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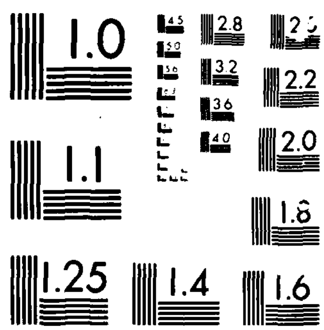

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This report summarizes 3 years of field studies at Lake Wallula, Washington-Oregon (McNary Reservoir), for the purpose of identifying plant species and revegetation techniques adaptable to reservoir shorelines within the US Army Engineer Districts, Portland and Walla Walla. The approach used was to subject transplanted vegetation to various inundation treatments and to evaluate survival and growth responses. The experimental design included

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plantings in a subimpoundment in which water levels were controlled, and on two shoreline sites (a mudflat and a sandy beach). Twenty-nine native and naturalized riparian species were tested.

In the controlled impoundment test site, willows (*Salix fragilis* and *Salix purpurea*), dwarf spikerush (*Eleocharis coloradoensis*), and two sedges (*Carex obnupta* and *C. rostrata*) were the most successful species. Inundation depth and duration were found to directly affect performance of the tested plant species. The impact of weather and wildlife confounded treatment effects on plant growth and survival at the shoreline sites. Only softstem bulrush (*Scirpus validus*) survived all inundation treatments on the shoreline for the duration of the study.

Results of this study show that several species have a potential for use in shoreline revegetation efforts. Environmental constraints other than flooding effects were identified, but means to mitigate their influence will require further study. The information gathered in this study is applicable to other shoreline sites on power production reservoirs in the region.

PREFACE

This report was prepared as part of the Environmental and Water Quality Operational Studies (EWQOS) Program, Task IIE.1, "The Environmental Effects of Fluctuating Reservoir Water Levels." The EWQOS Program is sponsored by the Office, Chief of Engineers (OCE), and is assigned to the US Army Engineer Waterways Experiment Station (WES), under the purview of the Environmental Laboratory (EL). The OCE Technical Monitors were Mr. Earl Eiker, Dr. John Bushman, and Mr. James L. Gottesman. Dr. J. L. Mahloch was the WES Program Manager of EWQOS.

The report was written by Dr. R. D. Comes and Mr. Timothy McCreary of the US Department of Agriculture (USDA), Agricultural Research Service (ARS), Prosser, Wash., and was submitted in fulfillment of a cooperative agreement among the USDA; the US Department of the Interior, Fish and Wildlife Service; and the WES. The ARS conducted the research in cooperation with the Washington State University Irrigated Agriculture Research and Extension Center, Prosser, Wash.

The original concept for this research was developed by Mr. Hollis Allen of the Wetlands and Terrestrial Habitat Group (WTHG), EL. Mr. Allen, Mr. Charles V. Klimas, and Dr. Stephen G. Shetron, WTHG, revised the manuscript. Mr. Darrel Sunday, Natural Resource Manager, Lake Wallula Project, US Army Engineer District, Walla Walla, provided valuable assistance during the conduct of the study. Ms. Jessica S. Ruff of the WES Publications and Graphic Arts Division edited the report.

The work was conducted under the direct supervision of Mr. Allen and Dr. Hanley K. Smith, Chief, WTHG, and under the general supervision of Dr. Conrad J. Kirby, Jr., Chief, Environmental Resources Division, and Dr. John Harrison, Chief, EL.

COL Allen F. Grum, USA, was Director of WES and Dr. Robert W. Whalin was Technical Director.

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CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
acres	4046.873	square metres
feet	0.3048	metres
feet per hour	0.3048	metres per hour
inches	2.54	centimetres
miles (US statute)	1.609347	kilometres
pounds (mass) per acre	0.000112	kilograms per square metre
square miles	2.589998	square kilometres

APPROACHES TO REVEGETATE SHORELINES AT LAKE WALLULA ON THE COLUMBIA RIVER, WASHINGTON-OREGON

PART I: INTRODUCTION

Background

1. From June 1979 to July 1982, personnel of the US Army Engineer Waterways Experiment Station; the US Department of the Interior, Fish and Wildlife Service, Biological Services; and the US Department of Agriculture (USDA), Agricultural Research Service, conducted a field study to identify plants suitable for revegetating denuded drawdown zones along the shoreline of Lake Wallula (McNary Reservoir) on the Columbia River. These areas are often unsightly, are conducive to accelerated bank erosion, and are often much less valuable as fish and wildlife habitat than vegetated shorelines.

2. Ten woody and 19 herbaceous species that were native or naturalized in the area were evaluated at three experimental sites established on the Oregon shore. The primary site was in the McNary Wildlife Park, where an impoundment was constructed that permitted precise control of the depth and duration of inundation. Two sites were along the shoreline of Lake Wallula: one was on a shallow mudflat and the other was on a sand beach. Depth and duration of inundation at the shoreline sites were variable, since water levels of the lake are dictated by power, flood control, navigation, and fisheries needs.

Study Area

3. Lake Wallula was formed in 1957 following completion of McNary Lock and Dam, a Corps of Engineers project operated primarily for the production of hydroelectric power. The dam is located at river mile 292 on the Columbia River, which, in this area, forms the

boundary between Washington and Oregon. At normal pool elevation, 340 ft* msl, the lake covers 38,000 acres and has a shoreline of 242 miles, extending into Umatilla County, Oregon, and Benton, Franklin, and Walla Walla Counties, Washington. The reservoir drains an area of approximately 215,000 square miles (US Army Corps of Engineers (USACE) 1975). Figure 1 is a regional map showing the location of Lake Wallula.

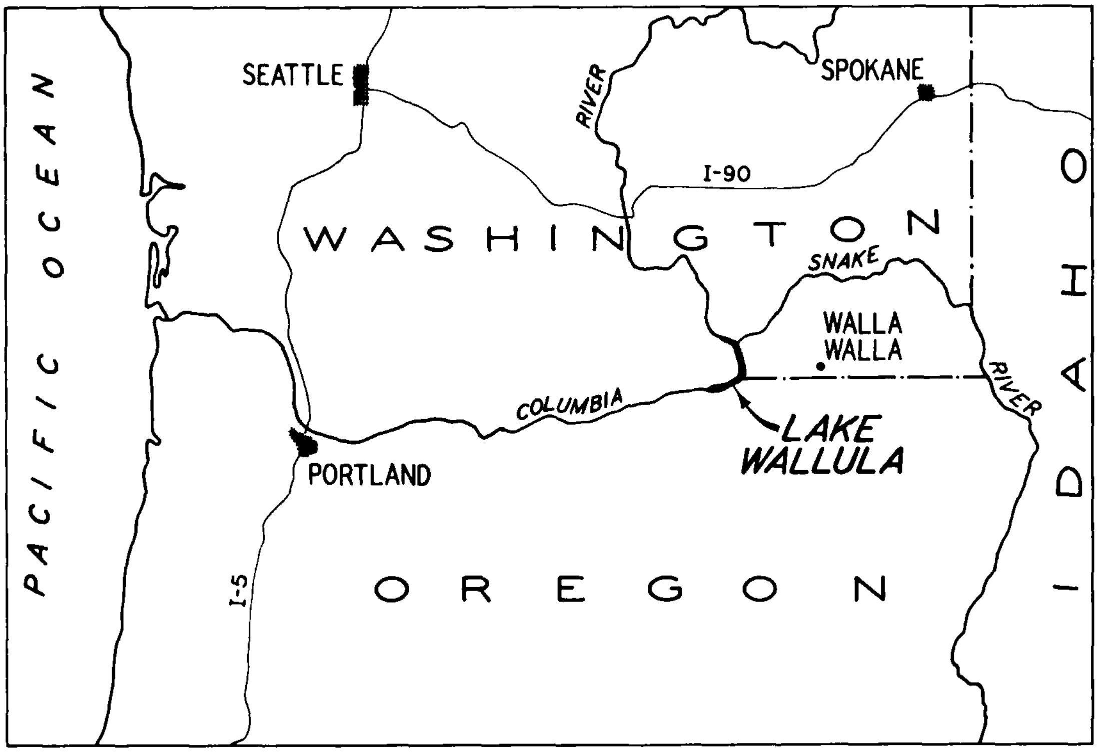

Figure 1. Regional map

4. A continental climate predominates in the study area, with wide daily and seasonal temperature fluctuations. Annual precipitation for the region is in the 10- to 20-in. range, although average annual precipitation at Umatilla, Oreg. (near McNary Dam), is only 7.83 in. Most of the regional precipitation (55 to 75 percent) falls between 1 October and 31 March and consists primarily of snow (Oregon Cooperative Wildlife Research 1976).

* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 3.

5. The geology of the study area is dominated by relatively recent formations, most notably the dark gray, fine-grained Columbia River basalt. Soils of the region are variable, although they are generally derived from alluvial materials and do not exhibit complex profile development.

6. The McNary Dam area is in the *Artemesia tridentata - Festuca* vegetation zone of the steppe region of eastern Washington and Oregon (Franklin and Dyrness 1973). Vegetation near the dam is of two distinct physiognomic types: steppe (or shrub-steppe) and riparian (riverbank) vegetation, which includes arboreal species (USACE 1975). The arid steppe vegetation is typical for the region and is characterized by a conspicuous shrub stratum including *Artemisia tridentata*, *Purshia tridentata*, *Atriplex spinosa*, and species of *Chrysothamnus*. The riparian vegetation is dominated by *Populus trichocarpa*, *Populus deltoides*, *Elaeagnus angustifolia*, and species of *Salix*. Other woody plants include *Morus alba*, *Ribes aureum*, and species of *Rosa*. Herbs and grasses found near the water's edge include species of *Carex*, *Juncus*, *Typha*, *Scirpus*, *Polygonum*, and *Phalaris* (USACE 1975).

PART II: METHODS AND MATERIALS

Site Preparation

7. In 1979, three field sites were established on the Oregon shore of the Columbia River. Two of these sites were within the fluctuation zone of the river: one on a protected mudflat at river mile 299 (Cold Springs) and the other on an exposed sandy beach at river mile 301 (Bobbie's Beach). The third site (Control Pool) was in a subimpoundment located in the southeast corner of the McNary Wildlife Park at river mile 291. The Control Pool was constructed to permit precise and consistent automated inundation treatment.

8. Composited soil samples from each site were analyzed to determine fertilizer requirements (Table 1). The prescribed materials (including a slow-release fertilizer) were applied with a centrifugal spreader, except for boron at Bobbie's Beach, which was applied as an aqueous spray. Fertilizer was incorporated by hand raking on the shoreline sites and by rototilling at the control pool.

Table 1

Fertilizer Recommendations by Site for the 1979 Growing Season

Location	Rate lb/acre	Fertilizer
Control Pool	560	18-6-12 (Osmocote)
	31	$ZnSO_4$
	3	B (Solubor)
	112	0-45-0 (Triple Super Phosphate)
Bobbie's Beach	560	18-6-12 (Osmocote)
	3	B (Solubor)
	168	0-45-0 (Triple Super Phosphate)
Cold Springs	560	18-6-12 (Osmocote)

9. Plots were established at three or four elevation contours (tiers) at each experimental site, as given in Table 2. The fluctuation

Table 2

Inundation Data for the Three Experimental Sites - Lake Wallula

Control Pool	Elevation ft msl	Depth of Maximum Inundation, ft
Tier 1 (T1)	--	4.5
Tier 2 (T2)	--	3.0
Tier 3 (T3)	--	1.5
Tier 4 (T4)	--	0
Bobbie's Beach		
Tier 1 (T1)	338	2
Tier 2 (T2)	339	1
Tier 3 (T3)	340	0
Cold Springs		
Tier 1 (T1)	337.5	2.5
Tier 2 (T2)	337.75	2.25
Tier 3 (T3)	338	2

limits of the Lake Wallula forebay are 335 to 340 ft msl. Thus, the plots at Bobbie's Beach planted at contour 340 were not inundated. Fluctuation limits at the control pool were controlled so that the upper tier (Tier 4) was not inundated (Table 2).

Plant Procurement

10. The native or naturalized species listed in Table 3 were collected from sites throughout Oregon or obtained from commercial or research nurseries in New York (*Salix purpurea* var. *nana*) or Montana (*Robinia*, *Ribes*, *Sambucus*, *Cornus*, *Elaeagnus*). Two herbaceous species were procured the preceding fall and kept in pots at a nursery in Florence, Oreg., during the winter and until they were needed for planting (*Eleocharis ovata* and *Trifolium wormskjoldii*). Starter plants of dwarf spikerush (*Eleocharis coloradoensis*) were provided by USDA researchers at the University of California, Davis, and multiplied in the USDA greenhouse at Prosser, Wash., until needed. The remaining species were procured from various Oregon sites in early spring and brought directly to the planting site.

Table 3

List of the Plant Species and Year Planted at the Control Pool and Lake Wallula Shoreline Sites

Herbaceous	Woody
1979	1979
Carex aperta	*Elaeagnus angustifolia*
Carex nebraskensis	*Morus alba*
Carex obnupta	*Ribes aureum*
Carex rostrata	*Robinia pseudoacacia*
Carex vulpinoidea	*Rosa multiflora*
Deschampsia caespitosa	*Salix fragilis*
Eleocharis coloradoensis	*Salix lasiandra*
Eleocharis ovata	*Salix purpurea* var. *nana*
Eleocharis palustris	*Sambucus cerulea*
Juncus balticus	
Juncus effusus	
Scirpus americanus	
Scirpus validus	
Typha latifolia	
Trifolium wormskjoldii	
1980*	1980**
Carex lyngbyei	*Cornus stolonifera*
Carex sheldonii	*Salix fragilis*
Polygonum persicaria	*Salix purpurea*
Sagittaria latifolia	

* Planted only at Cold Springs (shoreline).
** *C. stolonifera* planted at Control Pool and Cold Springs; *Salix* species planted at Cold Springs only.

Experimental Design

11. Design of each experiment was a complete randomized block with four replications of each species on each contour (tier). Woody and herbaceous species were not mixed in the design. The experiment was repeated on the north and south shores of the control pool. Thus, there were four replications on each bank, and data presented in this report are an average of those eight replications. The same plant species were used at each site (exceptions noted in Table 3), although the randomizations of blocks and plots within blocks were changed for each site. Each woody block contained eleven 1.5- by 2.4-m plots with 12 plants per plot on 0.6-m centers. Herbaceous blocks contained sixteen 0.4- by 1.2-m plots with 10 plants per plot on 20-cm centers. An alleyway, 60 cm wide, was left between plots to serve as a walkway and as a buffer zone between species.

Planting

12. Due to delays in site preparation and access, planting that had been scheduled to begin in late April or early May 1979 was delayed until the end of June and early to mid-July. During the delay, plants were held in buckets of water along ditchbanks in full sunlight or partial shade. Three weeks prior to planting, they were transferred to moist sawdust beds (woody species) or shallow plastic-lined boxes filled with water (herbaceous species) under deep shade. During this period, all of the woody species broke dormancy, although those procured from nurseries had been held in cold storage and were dormant when they arrived. Considerable leaf development occurred while they were held in the shade. Plants were maintained along ditchbanks and in deep shade a total of 40 to 70 days prior to transplanting. The mean maximum temperature was 26° C when the shoreline sites were planted in late June, and 35.5° C when the test pool was planted in mid-July. Temperature exceeded 39° C on each of the final 3 days that the test pool was planted. All plant materials were sets, slips, or rhizomatous plants that were topped to a height of 30 cm.

13. Plots at Bobbie's Beach and the test pool were irrigated daily during planting and for 30 days thereafter. Plots at Cold Springs were not irrigated because treatment (flooding) began immediately after planting was completed. Fluctuation treatments were begun 30 days after planting at the control pool.

Soil and Water Analyses

14. Each April, soil samples were collected from 10 random plots in each of the two woody blocks per tier at the control impoundment and Cold Springs. Three 2.5- by 30-cm cores were collected from each plot and subdivided by depth into 0- to 15-cm and 15- to 30-cm subsamples. A composite sample of each set of subsamples from each block was air dried immediately after collection and analyzed for the following characteristics:

a. pH.

b. Particle size distribution.

c. Cation exchange capacity.

d. Salinity.

e. Phosphorus.

f. Potassium.

g. Organic matter.

h. NO_3-nitrogen.

i. Total N (Kjeldahl).

15. Soil oxidation-reduction potential was determined by inserting 12 bright platinum electrodes* 15 cm into the soil in a circular pattern. The diameter of the electrode ring varied but was always less than 20 cm. The platinum electrodes were standardized in 0.1-percent ascorbic acid after the method described by Meek and Grass (1975). The millivolt meter** was calibrated using its own internal standard circuitry. The electrodes were allowed to equilibrate 24 hr before the

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* Jansen Instruments, PO Box 44021, Tacoma, Wash. 98440.
** Corning Model 610A, Corning Glass Works, Medfield, Mass. 02052.

voltage was recorded. The half-cell calomel was inserted 2 cm into the soil if the plots were not inundated or 2 cm into the water if the plots were inundated.

16. Dissolved oxygen and water temperature were measured at a depth of 30 cm using a Yellow Springs Model 54 oxygen-temperature meter. The oxygen meter was calibrated in air at the temperature of the water.

17. Water samples from each site were collected monthly, and turbidity was measured using a direct reading photometer.* These data are reported in Jackson Turbidity Units.

Plant Performance Variables

Survival

18. In 1979 and 1980, surviving herbaceous plants on each plot were counted 30 days after transplanting and at 1-month intervals during the growing seasons. A plant was considered to be surviving if any portion of the plant possessed green leaves or culms. During the first two seasons, the colonial growth habit of several herbaceous species made distinction of individual plants impossible. Therefore, in 1981 and 1982, survival data of herbaceous species reflect only whether or not a plot contained live plants. The surviving woody plants per plot were counted on each sampling date throughout the study.

Phenology

19. Each month, the phenological state of the plants in each plot was determined. The six phenological categories were: (a) vegetative, (b) tillering, (c) flowering, (d) anthesis, (3) fruiting, and (f) seed dispersal.

Vigor

20. Each month, the vigor of the plants in each plot was described according to the following categories: (a) dead, (b) declining (either toward death or dormancy), (c) stressed, (d) stable, (e) new shoot growth, (f) new rhizome growth, (g) dormant, (h) drought stress,

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* Model DR-EI, Hack Chemical Company, Ames, Iowa.

and (i) breaking dormancy. If the plants within a plot were producing both shoot and rhizome growth, the value assigned was for new rhizome growth.

Height and cover

21. Herbaceous plant height was measured to the nearest centimetre from the soil surface nearest the base of the plant to the tip of the longest leaf. One to ten height measurements were taken from each plot depending on the amount of plant cover that remained in the plot. Measurements were taken at the approximate location of each original plant. Thus, for example, if 80 percent of the plot contained plants, eight height measurements were taken in that plot. One of six cover values was assigned to each herbaceous plot to reflect the cover of living or dead plant material, as well as the bare soil area of each plot. These values and the percent cover they represent are given below.

Cover Value	Percent Cover
1	Less than 1
2	1-10
3	11-25
4	26-50
5	51-75
6	76-100

The data for each species presented in the figures in Part III are the mean of eight plots for the control pool.

22. In 1979 and 1980, the height of each surviving woody plant, from the soil to the tip of the highest surviving leaf, was measured to the nearest centimetre. From these data, the plot tier means were determined for each species. In 1981 and 1982, many of the woody plant canopies coalesced within their plots. On such plots, height of the tallest plant was measured and the tier-mean was calculated. The area covered by the plants was calculated by using the formula for the area of an ellipse. The 1979 and 1980 cover data represent the mean cover area per plot rather than per plant. This value was calculated by multiplying the mean survival per plot by the mean cover per plant.

Supplemental Data

Volunteer plants

23. Check plots were subsampled at the beginning and end of each season using a 15- by 30-cm rectangle to monitor the success of unplanted "volunteer" plants. Two subsamples were taken from herbaceous check plots, and five subsamples were taken from each woody check plot. The data are reported as the number of individuals of each species per square metre.

Wildlife, insects, and disease

24. Each plot was inspected monthly for evidence of wildlife utilization, insect damage, and disease symptoms. If any of the plants were threatened by wildlife, insects, or disease, appropriate corrective action was taken as necessary, available, or reasonable to correct or alleviate the condition.

Treatment

25. Treatment consisted of the unpredictable periodic fluctuation of the water level in the Lake Wallula forebay and controlled fluctuations at the control pool.

26. The forebay elevation of Lake Wallula is influenced by several competing interests and conditions. Among the more influential of these are runoff volume, power production, navigational requirements, and irrigation needs. Navigational requirements, by law, limit the maximum fluctuation in the forebay to 5 ft (335 to 340 ft msl).

27. Although the forebay was unpredictable at any particular instant, analysis of the hourly forebay elevations recorded in the McNary Dam control room showed that the pool did not fluctuate randomly. The forebay tended to fluctuate within the top 2 ft of the prescribed limits during the winter months, keeping the plants continuously flooded, while during summer months the elevation fluctuated below the contour level of the plots for relatively short time periods. A monthly summary of the mean number of hours per day the forebay was within a particular

shoreline contour (July 1979-July 1982) is presented as Table 4.

28. Normal treatment of the plants at the control pool consisted of fluctuating the water level 4.5 ft over a 24-hr period. The program changed the water level in 4-hr time blocks as depicted in Figure 2. The tiers were flooded and drained at the maximum rate that the equipment would permit (80 min or 0.71 ft/hour for flooding, and 100 min or 0.63 ft/hour for draining) and then held at that level for the remainder of the 4-hr period. Maintaining the pool elevation at its lowest point in early to mid-afternoon best approximated the Lake Wallula forebay fluctuations in summer. The control pool was held at full pool during the weekends and holidays, which also best simulated the forebay treatment. This fluctuation pattern produced the daily treatment presented in Table 5.

29. An alternate fluctuation pattern was used during data collection and plot maintenance. Such alternate patterns occurred during a 2-day period each month when survival, phenology, and vigor data were collected or over a 10-day period three times during the summer when height, cover, and survival data were collected. The alternate fluctuation brought the water over the plots at the maximum flooding and draining rate from 1600 hr to 0600 hr the following day. The pool was held at its lowest point during working hours. Thus, plants were inundated daily, but gained substantial atmospheric and photosynthetic exposure during data collection. Other significant variations occurred in the fluctuation pattern of the control pool during the winter of 1979-1980 and 1981-1982, when ice formation dictated maintaining full pool for various periods to avoid extracting woody plants during periods of low atmospheric temperature. These periods were for 41 days in 1980 and 33 days in 1982, during January and February. During the same period, the Lake Wallula forebay did not recede below the upper tier of either shoreline site.

30. Figure 3 presents the mean daily inundation of the Cold Springs site each month during the study. Analysis of variance indicated that the highest tier received a significantly different treatment than the middle and lowest tiers in 1980, but not in 1981.

Table 4

Summary of Lake Wallula Forebay Fluctuations, July 1979-July 1982

Year	Elevation ft msl	Mean Number of Hours per Day the Forebay Was at Each Elevation											
		Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
1979	339							3.1	4.8	5.2	6.0	10.6	11.8
	338							10.4	12.8	14.9	13.5	12.1	10.7
	337.75							2.1	2.1	2.3	1.4	1.1	0.5
	337.5							2.3	2.2	1.2	0.7	0.2	0.8
	<337.5							6.1	2.1	0.4	2.4	0.0	0.2
1980	339	4.9	10.5	8.0	5.4	20.0	17.8	12.5	4.7	8.5	4.2	6.8	14.8
	338	13.1	11.2	13.1	10.0	2.4	3.5	7.6	12.0	11.8	14.4	13.2	9.2
	337.75	2.0	1.4	1.1	2.6	0.3	0.7	1.1	1.5	1.3	2.2	1.8	0.0
	337.5	2.7	0.8	1.0	2.8	0.3	1.5	1.3	2.7	1.0	1.8	1.6	0.0
	<337.5	1.3	0.1	0.8	3.2	1.0	0.5	1.5	3.1	1.4	1.4	0.6	0.0
1981	339	10.1	16.3	17.5	4.4	12.3	16.7	12.3	6.8	3.6	3.9	10.1	13.9
	338	13.5	7.3	6.5	11.3	3.5	6.3	6.9	12.4	12.8	12.1	12.3	10.1
	337.75	0.4	0.0	0.0	1.5	2.5	0.3	1.2	2.5	2.7	2.2	0.6	0.0
	337.5	0.0	0.0	0.0	3.4	2.8	0.2	2.5	1.5	3.3	3.2	0.5	0.0
	<337.5	0.0	0.0	0.0	3.4	2.9	0.5	1.1	0.8	1.6	2.6	0.5	0.0
1982	339	16.1	13.0	22.7	17.2	14.7	3.6	20.9					
	338	7.8	10.4	1.3	5.1	1.4	0.4	1.3					
	337.75	0.1	0.6	0.0	0.2	0.5	0.1	0.4					
	337.5	0.0	0.0	0.0	0.9	1.2	1.6	0.5					
	<337.5	0.0	0.0	0.0	0.6	6.2	18.3	0.9					

Average for 37 Months

Elevation ft msl	Mean No. of Hours
339	10.6
338	9.2
337.75	1.1
337.5	1.3
<337.5	1.8

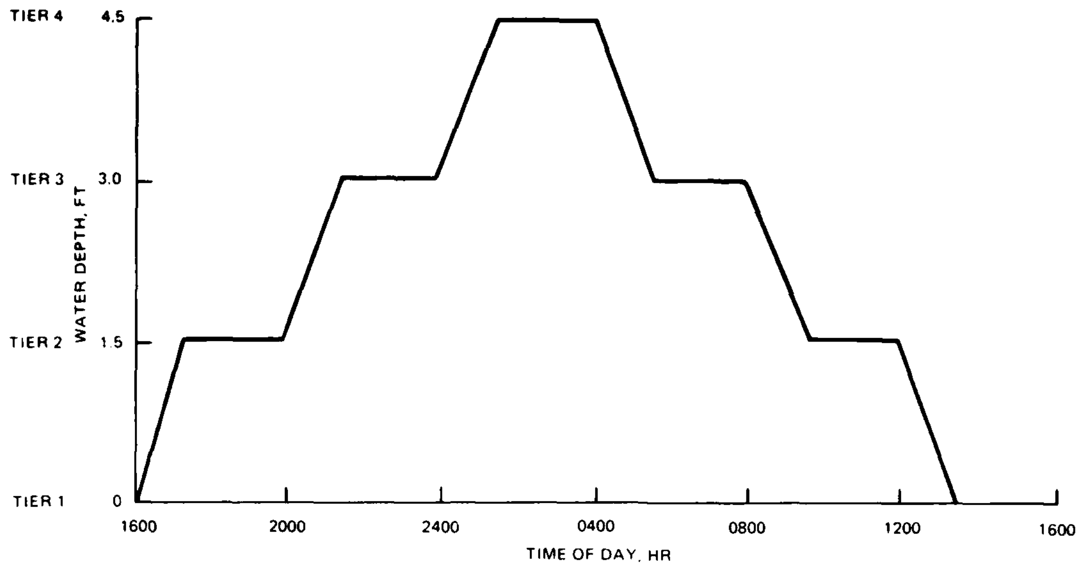

Figure 2. Control pool water fluctuation cycle

Table 5

Control Pool Treatment for 24-Hr Cycle

Tier	Depth of Inundation ft	Inundation Status	Duration hr
4	0.0	Not flooded	24.0
3	0.0-1.5	Flooded	2.0
		Partially flooded	4.4
		Not flooded	17.6
2	1.5-3.0	Flooded	10.0
		Partially flooded	4.4
		Not flooded	9.6
1	3.0-4.5	Flooded	18.0
		Partially flooded	4.4
		Not flooded	1.6

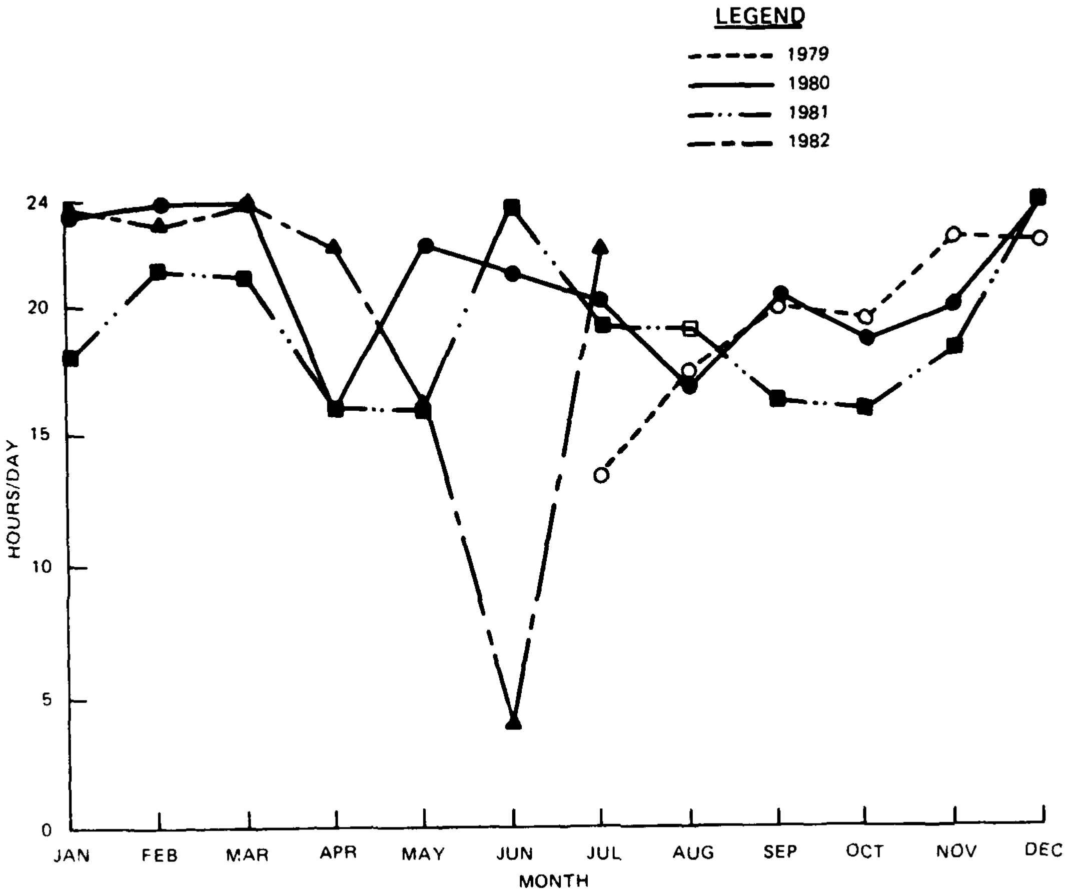

Figure 3. Mean daily inundation of plots at Cold Springs, Lake Wallula, 1979-1982

31. Throughout the remainder of this report, treatments will generally be referred to in terms of tier or maximum water depths. However, it should be remembered that these terms actually reflect the complex of factors discussed above, including the timing, duration, and seasonality of inundation.

PART III: RESULTS

Soil Conditions

32. The soil chemical and mechanical analyses are summarized in Tables 6-11. Soil pH and organic matter were stable at the control pool during the study. Nitrate nitrogen decreased after the first year and then remained stable. Total nitrogen remained relatively stable at both the shoreline and control pool, except in 1981 when there was an unexplained tenfold increase. Because total nitrogen reverted to its previous level after 1981, it is assumed that the analytical laboratory made a decimal error in 1981. Cation exchange capacity was low and remained stable, whereas salts were high and increased at Cold Springs. The decrease of phosphorus and potassium at the control pool would not be unusual for newly inundated terrestrial soil. The increase of these nutrients was not predicted at Cold Springs and suggests that siltation occurred on this site.

33. The mechanical analyses (Tables 8-9) show that the control pool soil underwent some change in composition once treatment began. Soil for the pool was transported from a nearby upland hill and was principally a loam. Inundation and wind erosion removed much of the silt content, changing the composition to sandy loam or loamy sand. The mudflat (Cold Springs) also underwent some change. The most substantial change occurred on Tier 1 in 1980 where the analysis showed a change from a sandy loam to a silt loam, indicating considerable siltation. Data from Bobbie's Beach indicate it was the most consistent site, with moderately high pH, low nutrient content, and unchanging texture.

34. Soil in Tier 1 at the control pool was moderately reduced and similar to that in Tier 3 at Cold Springs (Table 11). Tier 1 and Tier 2 at Cold Springs had the lowest soil oxidation-reduction (Eh) values. The most aerated soil was on Tier 3 at the control pool and could be considered moderately well aerated. The Eh data directly correlate with plant growth. However, due to the large variability associated with the technique for measuring soil Eh, not only in these data but in those

Table 6

Summary of Soil Chemical Parameters at the Control Pool, 1979-82*

Parameter	Tier	Year 1979	1980	1981	1982
pH	1	8.6	8.1	8.3	8.1
	2	8.6	8.1	8.3	8.0
	3	8.6	7.9	8.2	7.9
	4	8.9	8.3	8.3	8.1
% Organic matter	1	0.5	0.3	0.5	0.5
	2	0.4	0.4	0.5	0.5
	3	0.4	0.5	0.5	0.5
	4	0.4	0.4	0.5	0.5
Nitrate nitrogen (ppm)	1	8.2	1.9	1.8	1.9
	2	3.3	1.4	1.8	1.9
	3	3.1	1.4	1.6	1.8
	4	2.7	1.4	1.7	1.8
% Total nitrogen (Kjeldahl)	1	0.04	0.03	0.43	0.04
	2	0.04	0.03	0.45	0.04
	3	0.04	0.03	0.44	0.04
	4	0.04	0.02	0.39	0.04
Phosphorus (ppm)	1	9.7	6.5	4.5	5.5
	2	8.6	7.3	4.5	5.0
	3	7.8	7.5	4.8	5.3
	4	6.7	6.4	4.3	4.0
Potassium (ppm)	1	318	251	165	166
	2	330	327	174	154
	3	337	282	184	147
	4	388	370	343	304
Cation exchange capacity (meg/100 g)	1	9.6	9.6	10.1	6.6
	2	9.5	9.8	10.1	6.3
	3	8.5	9.6	10.1	6.6
	4	8.5	9.5	10.2	6.7
Salts (mmhos/cm^2)	1	0.33	0.24	0.27	0.49
	2	0.29	0.27	0.30	0.47
	3	0.27	0.31	0.32	0.50
	4	0.36	0.28	0.32	0.48

* Values are means of 0- to 15-cm and 15- to 30-cm samples taken in April from both sides of the control pool.

Table 7

Summary of Soil Chemical Parameters at Cold Springs, 1979-82*

Parameter	Tier	Cold Springs 1979	1980	1981	1982
pH	1	7.6	7.5	7.9	7.7
	2	7.5	7.5	7.9	7.8
	3	7.6	8.2	8.5	8.3
% Organic matter	1	0.1	0.4	0.6	0.4
	2	0.1	0.5	0.7	0.4
	3	0.1	0.3	0.5	0.4
Nitrate nitrogen (ppm)	1	0.9	0.1	1.7	2.2
	2	0.9	0.2	2.0	2.4
	3	1.0	0.8	2.2	2.1
% Total nitrogen (Kjeldahl)	1	0.02	0.02	0.48	0.05
	2	0.02	0.02	0.65	0.05
	3	0.02	0.01	0.41	0.05
Phosphorus (ppm)	1	0.3	7.5	7	9
	2	0.5	9.3	10	9
	3	0.8	6.2	6	6
Potassium (ppm)	1	57	250	241	223
	2	57	261	230	213
	3	70	381	469	369
Cation exchange capacity (meg/100 g)	1	4.7	8.5	8.8	6.1
	2	4.7	9.4	10.0	7.2
	3	4.5	10.1	9.5	7.2
Salts (mmhos/cm^2)	1	0.11	0.76	0.72	1.46
	2	0.11	0.62	0.75	1.36
	3	0.11	0.40	0.65	1.38

* Values are means of 0- to 15-cm and 15- to 30-cm samples taken in April.

Table 8

Summary of the Mechanical Analysis of Soils at the Control Pool, 1979-1982

Parameter	Tier	1979	1980	1981	1982
		Year			
% Rock	1	--	0.0	--	--
	2	--	0.4	--	--
	3	--	0.0	--	--
	4	--	0.2	--	--
% Sand	1	31.0	64.5	73.5	64.9
	2	38.5	65.2	73.3	65.0
	3	44.4	64.4	72.8	63.5
	4	44.0	61.9	73.4	65.3
% Coarse silt	1	42.6	27.8	24.1	30.3
	2	38.9	27.2	24.5	29.7
	3	40.0	29.3	24.3	31.4
	4	38.8	26.3	23.9	29.4
% Fine silt	1	5.4	1.7	1.3	1.2
	2	6.0	0.8	1.4	1.5
	3	3.3	0.6	0.9	1.1
	4	4.2	2.9	1.1	0.7
% Clay	1	21.0	6.0	1.1	3.6
	2	16.6	6.4	0.8	3.8
	3	12.3	5.7	2.0	4.0
	4	13.0	8.6	1.6	4.6
Class	1	Loam	Sandy loam	Loamy sand	Sandy loam
	2	Loam	Sandy loam	Loamy sand	Sandy loam
	3	Loam	Sandy loam	Loamy sand	Sandy loam
	4	Silt loam	Sandy loam	Loamy sand	Sandy loam

Table 9

Summary of the Mechanical Analysis of Soils at Cold Springs, 1979-1982

Parameter	Tier	1979	1980	1981	1982
% Rock	1	--	--	--	--
	2	--	--	--	--
	3	--	--	--	--
% Sand	1	68.4	22.6	74.0	65.2
	2	58.9	51.0	71.9	56.9
	3	54.3	53.0	65.2	55.8
% Coarse silt	1	26.0	54.2	24.0	30.2
	2	35.4	41.9	25.5	38.9
	3	39.3	40.6	32.1	38.8
% Fine silt	1	1.5	4.2	0.9	0.6
	2	1.1	1.3	1.1	1.2
	3	1.3	0.8	1.2	0.8
% Clay	1	4.1	19.0	1.3	4.0
	2	4.6	5.8	1.6	3.0
	3	5.1	5.6	1.7	4.6
Class	1	Sandy loam	Silt loam	Loamy sand	Sandy loam
	2	Sandy loam	Sandy loam	Loamy sand	Sandy loam
	3	Sandy loam	Sandy loam	Sandy loam	Sandy loam

Table 10

Summary of Selected Physical and Chemical Properties of Soils at Bobbie's Beach, 1979-1982

Parameter	Tier*	Year**			
		1979	1980	1981	1982
pH	2	7.5	7.9	7.8	7.9
% Organic matter	2	0.1	0.1	0.1	0.6
Nitrate nitrogen (ppm)	2	0.9	0.23	0.9	1.1
% Total nitrogen (Kjeldahl)	2	0.02	0.12	0.08	0.014
Phosphorus (ppm)	2	0.5	0.5	1.0	1.0
Potassium (ppm)	2	57	68	93	67
Cation exchange capacity (meg/100 g)	2	4.7	5.3	4.5	3.6
Salts (meg/100 g)	2	1.2	0.14	0.08	0.28
% Sand	2	98.1	96.5	96.2	99.0
% Coarse silt	2	0.8	1.5	1.2	0.2
% Fine silt	2	0.4	0.3	2.0	0.1
% Clay	2	0.7	1.8	0.6	0.7
Class	2	Sand	Sand	Sand	Sand

* After the majority of the plots were washed away, only one soil sample (30 cores) was taken from approximately the Tier 2 elevation.

** Values reported for 1980 are fall values; those for 1979, 1981, and 1982 were taken in the spring.

Table 11

Summary of Soil Oxidation-Reduction Potentials, 1979-1982*

Site	Tier	1979	1980	1981	1982	Mean
Control Pool	1	71	285	170	130	164
	2	309	327	290	266	298
	3	446	339	327	520	408
	4	547	365	277	275	366
Cold Springs	1	--	-105	38	139	24
	2	--	186	-149	156	64
	3	--	103	132	142	126

* Values reported are year-end (Sep-Oct) values.

reported in the literature, differences in plant growth cannot be confidently attributed to variation in soil Eh.

Water Quality

35. Dissolved oxygen and water temperature data are given in Tables 12 and 13. Dissolved oxygen ranged from 7.6 ppm on the river in August 1979 to 13.5 ppm on the river in June 1980. Values in any particular month did not vary more than 2.4 ppm (September 1980) between sites. These data show that there was not a substantial difference in dissolved oxygen between the control pool and the river during the course of the experiment.

36. Water temperature ranged from 13° C at the control pool in October 1980 to 28° C at the control pool in June 1981. The difference between the shoreline sites and the control pool in a given month ranged from 0° C (April 1980) to 11° C (April 1981). There was no trend in the number of times the pool was warmer or cooler than the river. During the study, water in the control pool averaged 1° C colder than in the river.

37. Water turbidity was low, with a mean of 20.8 JTU for the

Table 12

Summary of Dissolved Oxygen (ppm), 1979-1982

Month	Site*	1979	1980	1981	1982
April	CP	--	11.4	9.6	--
	River	--	11.2	9.7	--
May	CP	--	10.0	10.4	11.2
	River	--	12.0	10.3	10.7
June	CP	--	11.2	12.2	11.2
	River	--	13.5	11.1	10.4
July	CP	--	9.0	10.1	--
	River	--	8.0	10.1	--
August	CP	8.2	9.6	10.2	
	River	7.6	10.5	8.7	
September	CP	8.2	9.6	10.6	
	River	8.4	12.0	10.0	
October	CP	9.4	10.6	--	
	River	10.1	11.3	--	

* CP = Control Pool; value for river is the mean of the values obtained at the two shoreline sites.

Table 13

Summary of Water Temperature (° C), 1979-1982

Month	Site*	1979	1980	1981	1982
April	CP	--	14	13	--
	River	--	14	24	--
May	CP	--	20	18	15
	River	--	15	21	14
June	CP	--	19	28	20
	River	--	22	23	17
July	CP	--	21	25	--
	River	--	24	24	--
August	CP	21	19	24	
	River	23	25	21	
September	CP	16	20	14	
	River	22	19	16	
October	CP	17	13	--	
	River	16	15	--	

* CP = Control Pool; value for river is the mean of the values obtained at the two shoreline sites.

Table 14

Summary of Water Turbidity (JTU), 1979-1982

Month	Site*	1979	1980	1981	1982
April	CP	--	48	30	--
	River	--	20	23	--
May	CP	--	15	20	20
	River	--	25	28	24
June	CP	--	15	40	10
	River	--	20	23	18
July	CP	--	25	15	--
	River	--	25	18	--
August	CP	13	10	20	
	River	17	10	18	
September	CP	12	15	15	
	River	13	18	13	
October	CP	42	10	--	
	River	14	3	--	

* CP = Control Pool; value for river is the mean of the values obtained at the two shoreline sites.

control pool and 18.1 JTU for the river (Table 14). The highest value recorded (48) was in April 1980 in the control pool, and the lowest value (3) was in October 1980 in the river. Turbidity probably did not influence plant growth substantially, although the silt deposited on foliage was considerable at times throughout the study.

Transplant Performance - Control Pool

38. Twenty-one of the 29 species evaluated were successful on at least one contour at the control pool. Three herbaceous and two woody species were successful at all flooding depths, which ranged from 1.5 to

4.5 ft. With the exception of the three *Salix* species, none of the woody plants performed well where flooding depth was more than 1.5 ft, but 9 of the 19 herbaceous species were well adapted to flooding depths of at least 3 ft. Herbaceous plants that performed best at the maximum flooding depth of 4.5 ft were *Carex* spp. and *Eleocharis* spp.

39. Transplant performance and use by wildlife are discussed on an individual species basis. The values given in the following discussion pertain to data from the control pool only.

Herbaceous species

40. *Carex aperta.* More than 95 percent of the plants survived the year of establishment, but survival declined to between 64 and 78 percent on a plants/plot basis the second year (Figure 4). With the exception of Tier 3 (the second highest elevational tier), where all plants in one of eight plots died, survival on a plot basis was 100 percent throughout the experiment. Cover remained rather static at about 25 to 50 percent with the exception of Tier 2 (the second lowest elevational tier), where cover increased annually to a final level of nearly 100 percent. Height of plants at the termination of the experiment was inversely proportional to the depth (and duration) of flooding. Height ranged from 24 cm on Tier 4 to 93 cm on Tier 1.

41. *C. aperta* suffered chronic chlorosis throughout the experiment. The degree of chlorosis was equal among plants on Tiers 2, 3, and 4 but sometimes was nondetectable on Tier 1. The symptoms often receded in late fall, but reappeared in early spring and became most severe during seed production.

42. The only apparent wildlife usage associated with this species was the occurrence of two small mammal burrow entrances within two plots on the nonflooded tier (Tier 4).

43. Although the survival of this species equaled or exceeded that of other herbaceous species on all tiers, it appears to be most adapted to the zones flooded to depths of 1.5 to 4.5 ft.

44. *Carex lyngbyei.* This species was planted at Cold Springs in 1980, but it was not planted at the control pool. A demonstration plot planted at Cold Springs in 1979 indicated the species had good potential.

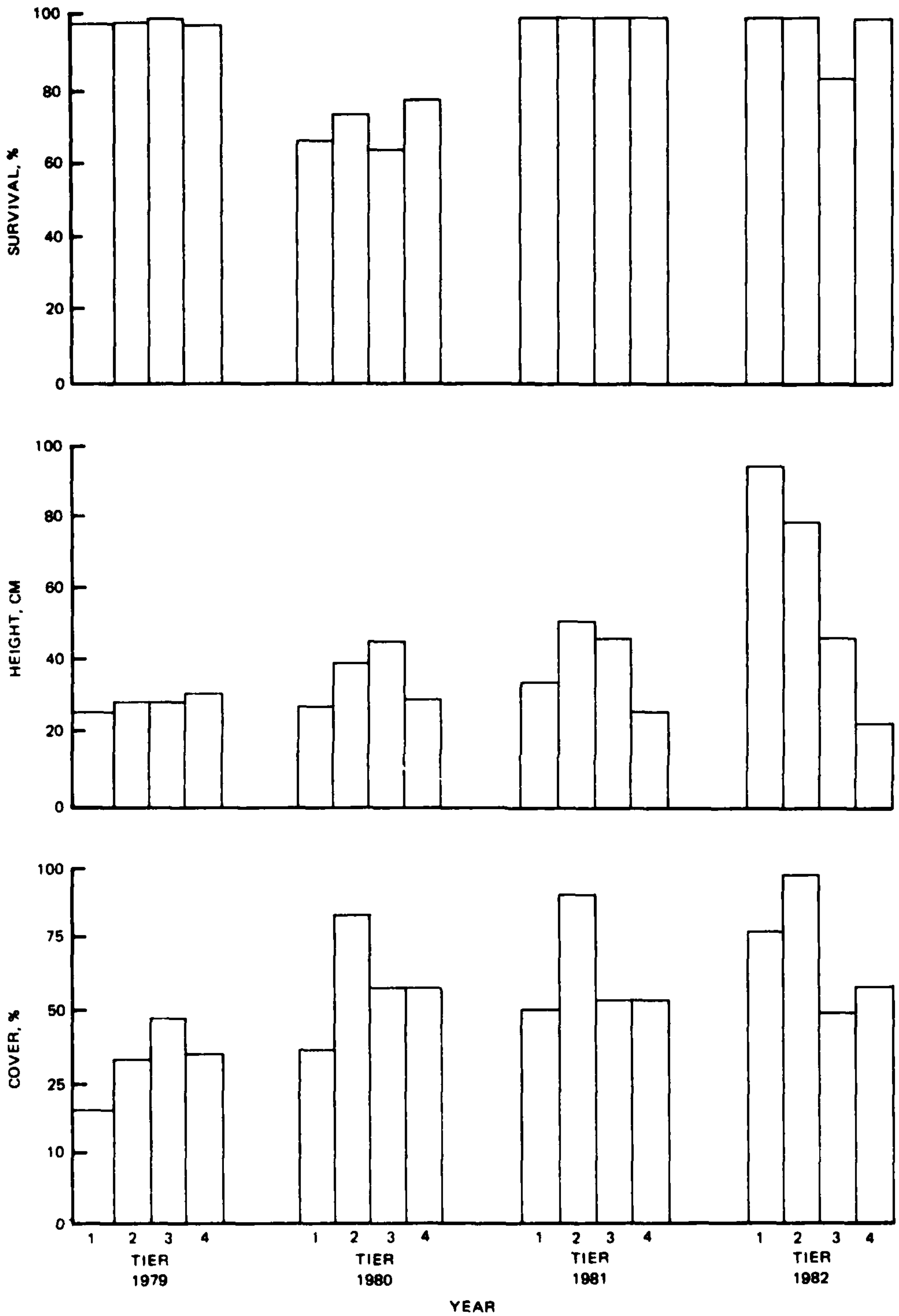

Figure 4. Survival, height, and cover of *Carex aperta* at four flooding depths at the control pool

However, after its initial excellent establishment, survival declined until it nearly died out by September. The species did not survive the winter. No disease symptoms, wildlife, or insect utilization were observed on this species.

45. *Carex nebraskensis.* Initial survival of *C. nebraskensis* was 68 to 85 percent and remained higher than 60 percent on the upper three tiers (Figure 5). The species had a high first winter mortality on the lowest tier and never recovered appreciably. Survival on the upper three tiers remained high (100 percent) on a plot basis throughout the experiment.

46. Cover increased dramatically from the first to second growing season on Tiers 2 and 3 and remained high on Tier 2. Cover on Tier 3 decreased sharply in 1982. This species did not grow well under long inundation or dry conditions. Plant height and cover exhibited similar trends on a tier basis. Maximum plant height (84 cm) was on Tier 2 in 1982.

47. Wildlife use of this species was not apparent during the experiment. Chronic chlorosis appeared during the first season and continued throughout the experiment. The symptoms appeared principally in the upper two tiers. Chlorosis would characteristically occur sporadically within a plot, and the severity would typically range from none to completely chlorotic with the newer shoots exhibiting the least chlorosis. A mild rust infection occurred in 1981 and 1982.

48. The survival and cover data indicate that *C. nebraskensis* could be suitable for use in the moderate drawdown zone (1.5 to 3 ft) but that it would be unsuitable for the lower drawdown and upland environments.

49. *Carex obnupta.* Initial survival was mediocre and ranged from 37 percent on Tier 1 to 67 percent on Tier 3 (Figure 6). Several plants died during the 1979-1980 winter, but some plants persisted in all plots, except one on Tier 1. The high survival rates (on a plot basis) were accompanied by consistent rhizome production which filled in the plots by the middle of the third summer on Tiers 2 and 3. Growth was slower on the lowest tier, but eventually these plots began to fill in and

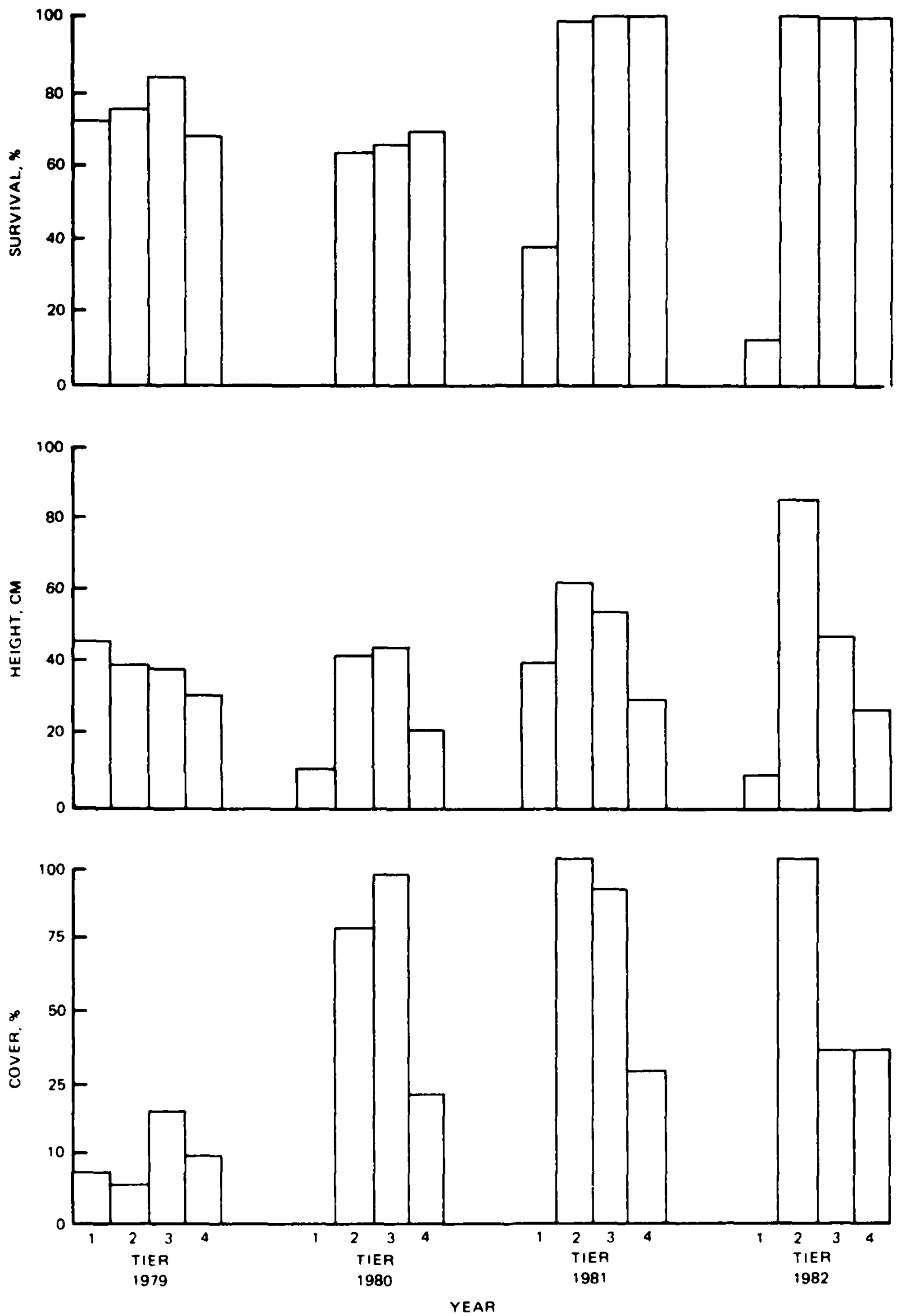

Figure 5. Survival, height, and cover of *Carex nebraskensis* at four flooding depths at the control pool

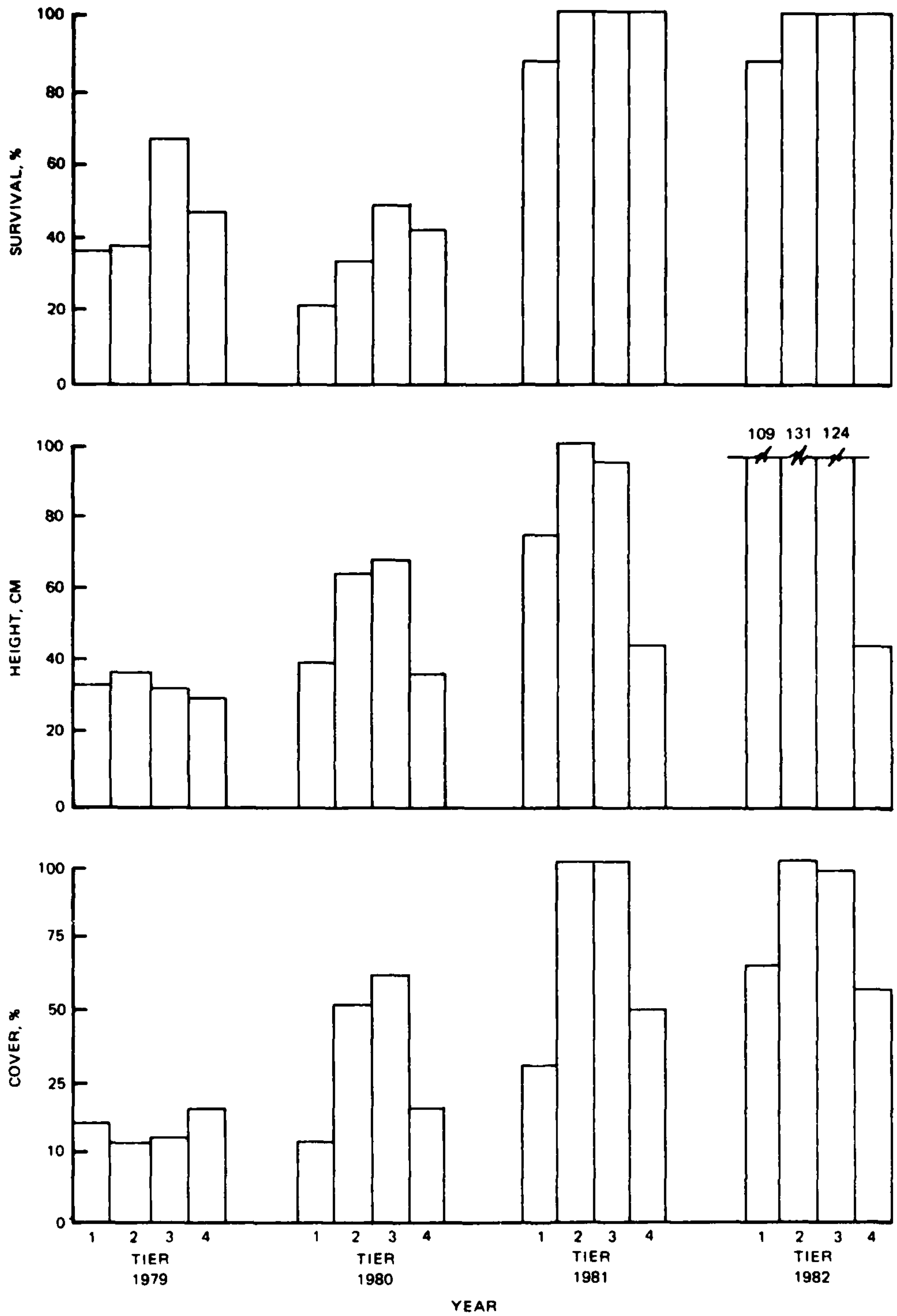

Figure 6. Survival, height, and cover of *Carex obnupta* at four flooding depths at the control pool

approached 75-percent cover. Rhizome growth was much slower on the nonflooded tier.

50. Height of *C. obnupta* was second only to river bulrush (*Scirpus validus*) among herbaceous species. Plant height increased each season and reached a maximum height of 131 cm on Tier 2 in 1982.

51. There was no evidence of wildlife usage, even when the plants were heavily laden with seed in 1981. No major plant diseases were noted except for mild chlorosis and a mild rust infection.

52. Despite its low initial survival, the robust growth exhibited by this species indicates that *C. obnupta* is adapted to the drawdown zone to a depth of 4.5 ft. Although it survived well on the noninundated tier, growth was restricted.

53. *Carex rostrata*. Forty to 50 percent of the plants died during the year of establishment, but few plants died during the ensuing winter. Some plants survived on all tiers, and these spread gradually through rhizome extension, especially on the three inundated tiers. On the lower three tiers, 50 to 100 percent of the plot area was covered by this species during 1981 and 1982 (Figure 7). Growth on the lowest tier was second only to *Eleocharis coloradoensis* and *C. obnupta*. Maximum plant height increased to slightly over 1 m on the second tier in 1982.

54. With the exception of one or two small mammal burrows on Tier 4, there was no evidence of wildlife usage.

55. Chlorosis occurred in this species, and its severity increased as depth of inundation decreased. In 1980 the chlorosis was severe, but subsided as the season progressed. In 1981, the condition increased in intensity as the year progressed. In 1982, the intensity remained mild to moderate on the inundated tiers and moderate to severe on the noninundated tier.

56. *C. rostrata* has excellent potential for revegetation within the drawdown zone to the maximum depth tested (4.5 ft). It does not appear to be suited for upland habitats. This species produced a total of only three inflorescences throughout all tiers, sites, and years of the study.

57. *Carex sheldonii*. This species was planted at Cold Springs

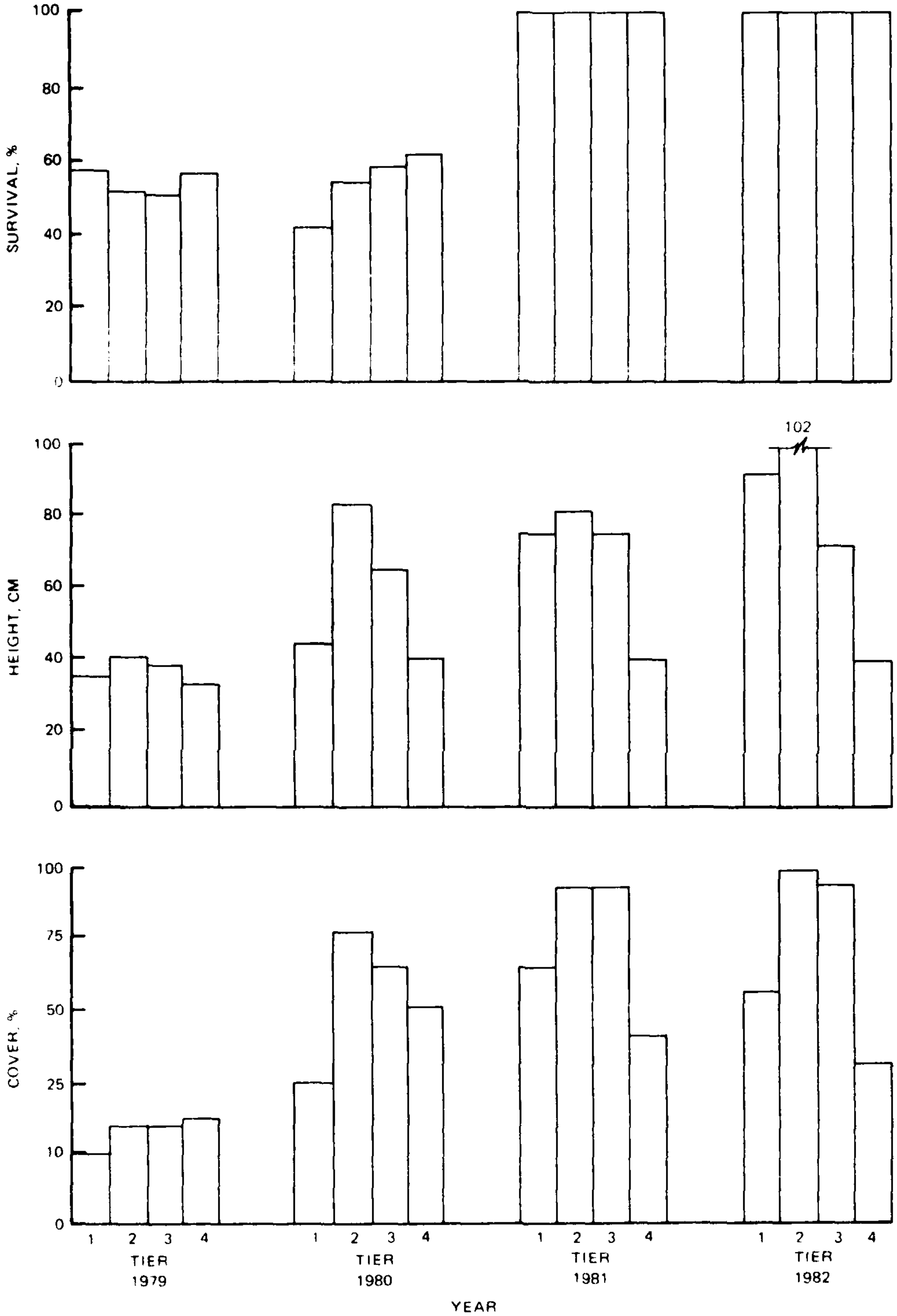

Figure 7. Survival, height, and cover of *Carex rostrata* at four flooding depths at the control pool

only in 1980. Initial survival was 85 percent or more on all tiers, but growth was poor and all plants died before September.

58. *Carex vulpinoidea*. *C. vulpinoidea* had better initial survival (62 to 82 percent) than other *Carex* species included in the experiment. As with most other species, individual survival decreased in the second year, but survival on a plot basis stabilized in 1981 and 1982 (Figure 8).

59. Cover increased on all tiers except the lowest (Tier 1) during the first three seasons, and then stabilized at 75 to 100 percent on Tiers 2 and 3 and 25 to 50 percent on Tier 4. Plant height reached its peak of slightly under 100 cm on Tier 2 in 1982.

60. No wildlife appeared to use this species. The only disease noted was chronic chlorosis, which varied in severity but was usually mild. Chlorosis was most severe in 1982 on Tiers 3 and 4.

61. This species exhibited good first-year survival and slow expansion thereafter. The increase in cover was not due so much to new plant initiation as to increasing foliage production. However, flower production ranked near that of *Deschampsia caespitosa*, and numerous seedlings emerged throughout the control pool. This species appears to be most adapted to drawdown zone depths ranging from 0 to 3 ft.

62. *Deschampsia caespitosa*. Initial survival of *Deschampsia caespitosa*, 98 to 100 percent, was among the highest for any species in the experiment. More than 50 percent of the plants died on Tier 1 during the first winter (Figure 9), but some plants survived in all except two plots for the duration of the experiment.

63. Cover on the three upper tiers was more than 75 percent during 1980, but it declined thereafter, especially on Tiers 3 and 4.

64. Wildlife usage was implicated in the decreased survival on Tier 3 in 1982 and in the decline in cover on the upper two tiers. In the winter of 1980 and again in 1981, muskrats used the *Deschampsia* plots on Tiers 2 and 3 for cover. They burrowed along the soil surface and between the two rows of plants, entering from the low end of the plot. During the following summer, several plants died in these plots. Two or three plots were disrupted by muskrats that burrowed into the

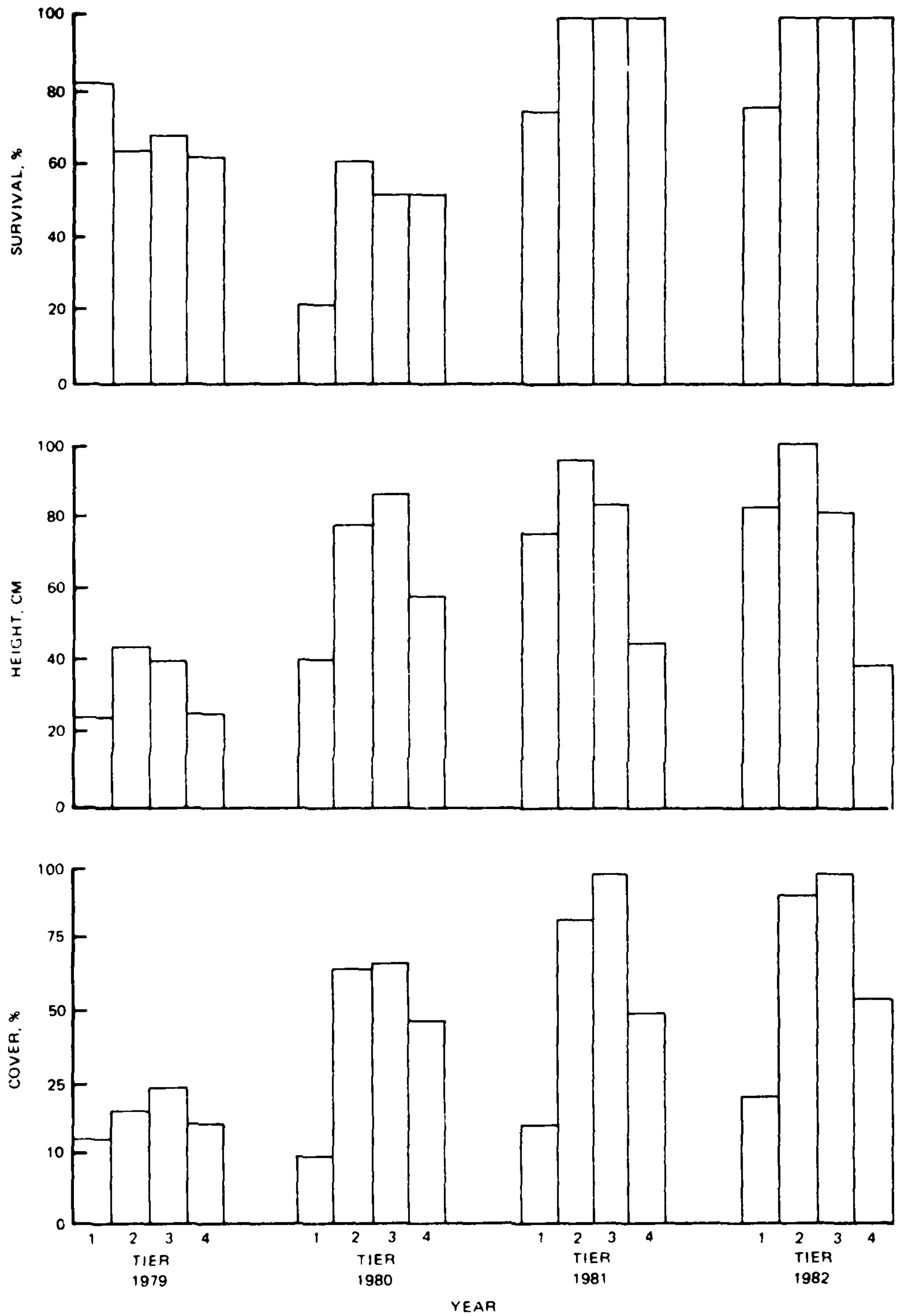

Figure 8. Survival, height, and cover of *Carex vulpinoidea* at four flooding depths at the control pool

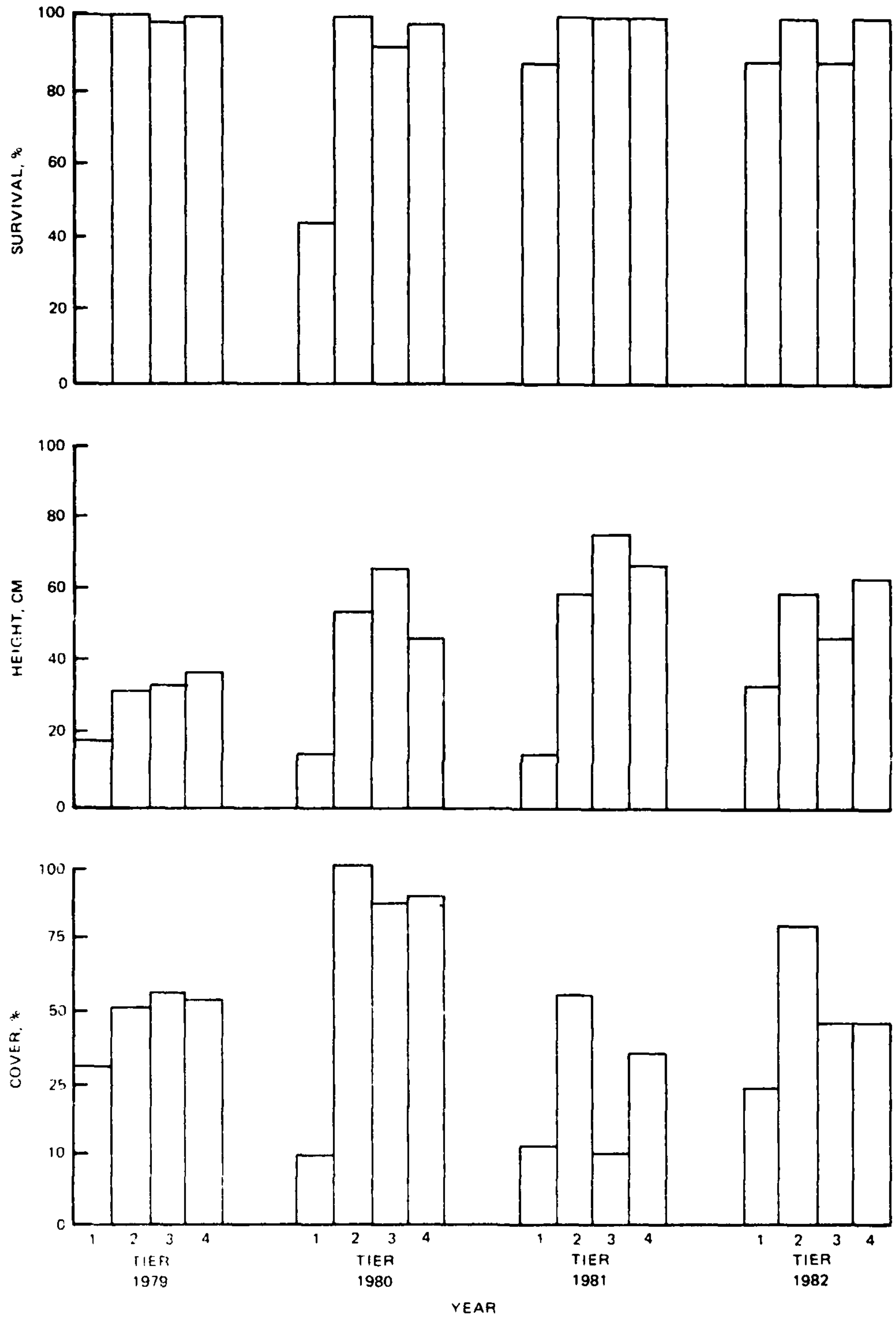

Figure 9. Survival, height, and cover of *Deschampsia caespitosa* at four flooding depths at the control pool

soil and destroyed several plants. Muskrats did not use any other species in this manner. *Deschampsia* suffered slightly from chlorosis and a rust infection.

65. This species produced abundant seed each year on all but Tier 1. The seed was dispersed over the entire area of the control pool, and the resultant seedlings became one of the dominant volunteer species. Under the proper establishment conditions, seeding would be the most economical means of establishment.

66. Although the species produced new culms each year, the number of new culms decreased each season after the second. Since each culm has the potential to flower and then dies, *Deschampsia* cannot be expected to maintain the initial population nor to maintain a constant seed supply. Therefore, this species is most suited to the upper drawdown zone and marsh areas where the environment is conducive to seedling production.

67. *Eleocharis coloradoensis*. Nearly 100 percent of the *Eleocharis coloradoensis* plants (plugs) became established on the three inundated tiers, but none established on Tier 4, the highest tier. Shortly before survival data were recorded in October 1979, waterfowl extirpated all plants from the plots on Tier 3. However, some tubercles and/or rhizomes apparently remained in the soil and sprouted in 1980. Eventually, the activity of ducks reduced the population on Tier 3 to zero (Figure 10).

68. Plant cover increased steadily on Tier 1 (the lowest tier) until cover was virtually 100 percent. Reasons for the decrease in cover on Tier 2 between 1981 and 1982 are not clear, and the data are not representative of Tier 2 in general. Volunteers of this species performed well on Tier 2. *E. coloradoensis* is a diminutive plant, and height ranged between 1 and 2 cm.

69. Wildlife usage was consistent each year. Waterfowl fed on the tubercles, extirpating plots and colonies established outside the plots. No other wildlife usage was observed.

70. This species was considered to be one of the most successful. Although the data do not document this view, except on Tier 1, general

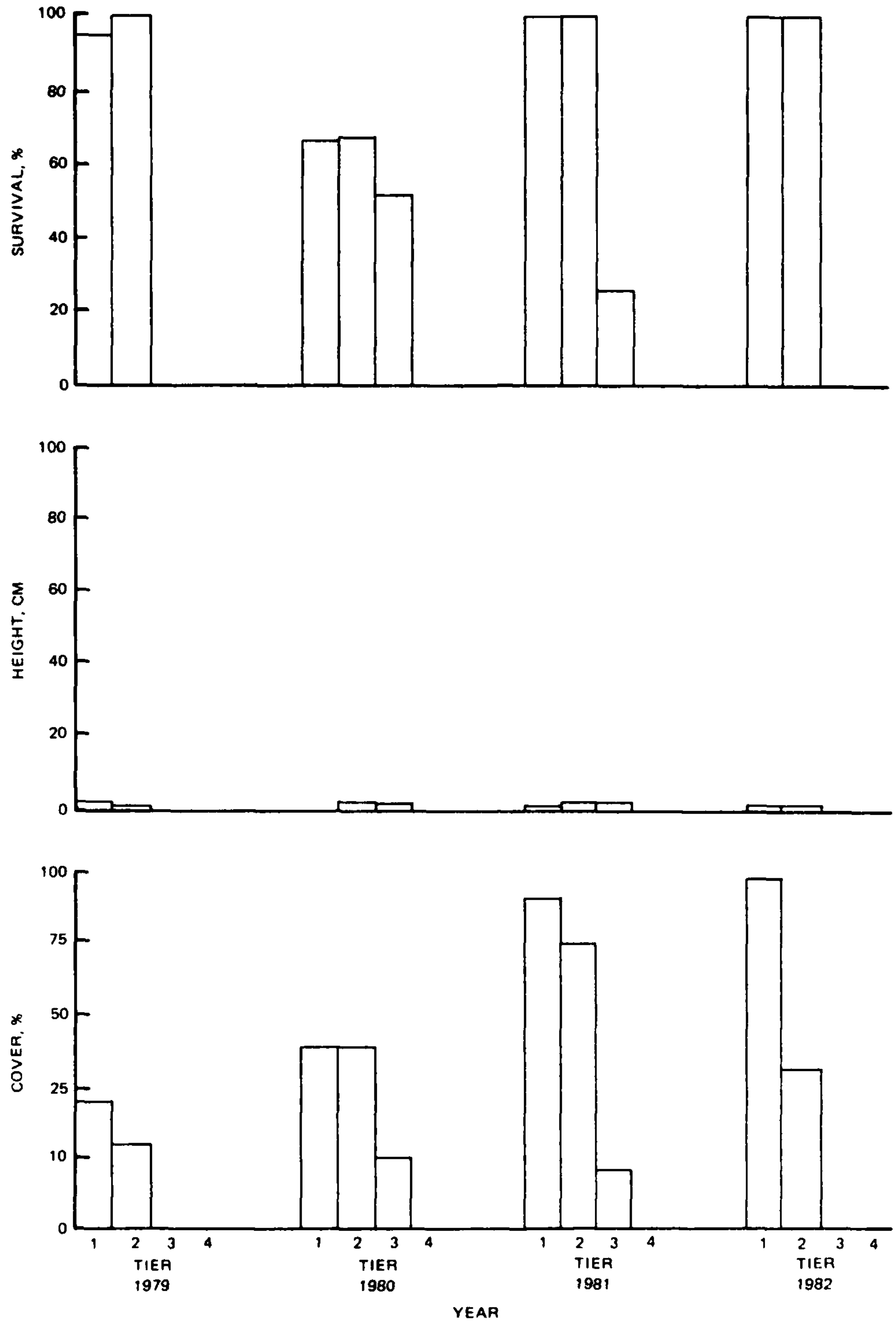

Figure 10. Survival, height, and cover of *Eleocharis coloradoensis* at four flooding depths at the control pool

observations and data from the check plots substantiate this opinion. Waterfowl extirpation essentially eliminated the tubercles from the plots on Tier 3, and the plants did not reestablish themselves, probably because the seed and tubercles produced by the original plants floated downslope. Rhizome growth tended to be downslope as well. The movement of reproductive structures aided in distributing the species into virtually a carpet from one end of the control pool to the other in Tiers 1 and 2. This species is well adapted to flooded conditions and probably would grow luxuriantly in drawdown zones (at least to 4.5 ft) if the activity of ducks could be curtailed, or if new tubercles or seed were planted periodically to reestablish the colonies following feeding by ducks.

71. In 1979, a closely related species (*Eleocharis parvula*) performed similarly in the upper drawdown zone at the Cold Springs mudflat site. Waterfowl also extirpated this population in 1979, and in the following three summers, the population did not reestablish itself. Siltation may be one of the principal reasons why the population did not recover at Cold Springs.

72. *Eleocharis ovata*. Ninety-eight to 100 percent of the plants became established, and survival during the first winter (1979-1980) was excellent on the upper three tiers (Figure 11). This species also reproduced by seed after the first season. However, it began to decline in 1980 and survival, height, and cover decreased steadily until 1982 when all plants in all tiers died.

73. Wildlife apparently did not utilize this species at the control pool. Chronic chlorosis was slight to sometimes severe.

74. The performance of this species indicates that it is unsuitable for use in revegetation of the drawdown zone or in upland environments with conditions similar to those at the control pool. However, the species forms an extensive monotypic colony in the marsh where it was collected near Mapleton, Oreg., and it may have potential in other environments.

75. *Eleocharis palustris*. Initial survival of this species was only 50 percent on Tiers 1 and 4, but ranged up to 81 percent on Tier 3

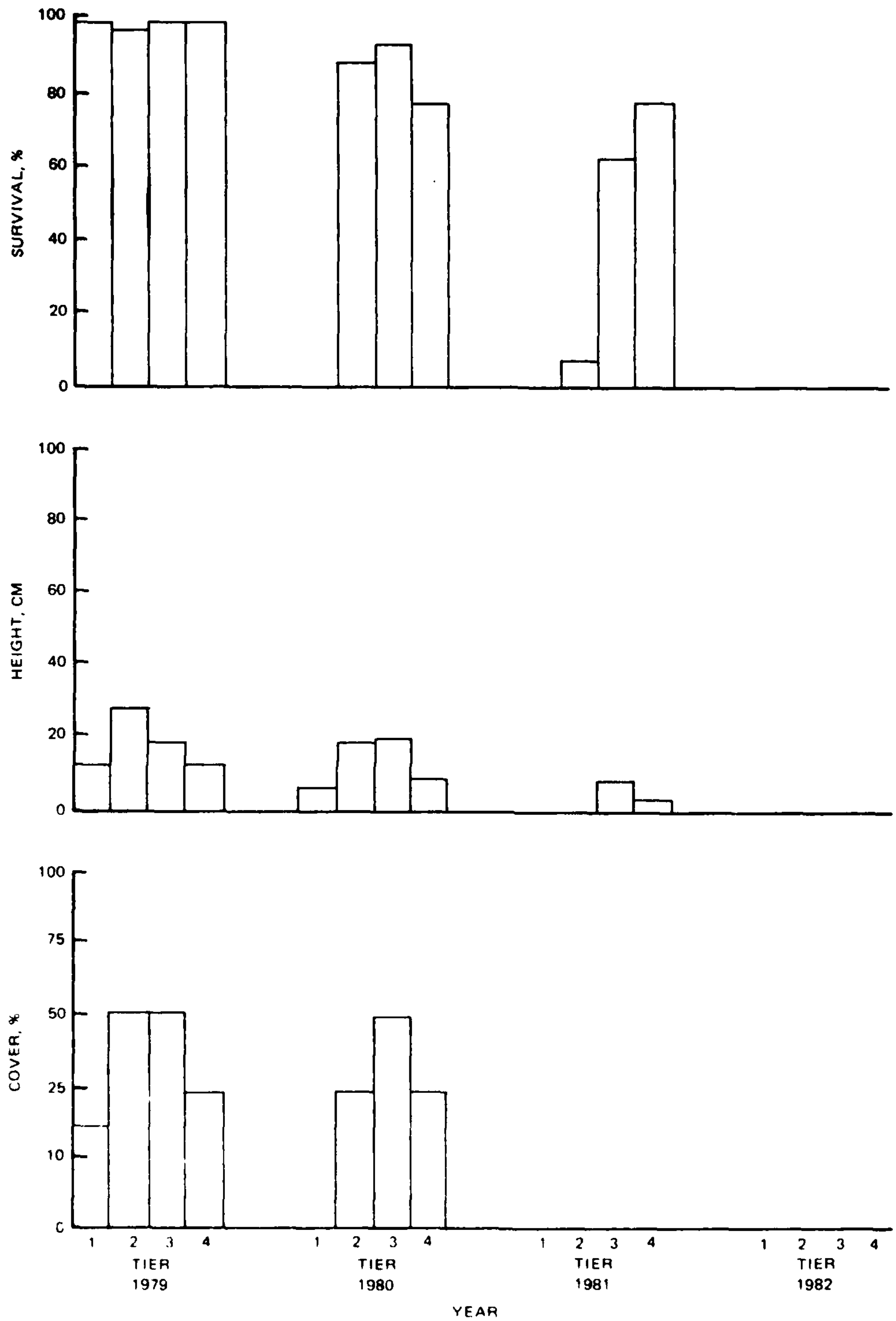

Figure 11. Survival, height, and cover of *Eleocharis ovata* at four flooding depths at the control pool

(Figure 12). As with most species, several plants died during the first winter, and survival in 1980 ranged from 17 percent on Tier 1 to 58 percent on Tier 3. Some plants survived in all plots on the upper three tiers for the duration of the study. Plants attained a height of 29 to 36 cm during each of the 3 years after establishment.

76. Cover increased dramatically on Tiers 2, 3, and 4 during the year after establishment, remained relatively constant in 1981, and then decreased slightly in 1982. Maximum cover (50 to 75 percent) was on Tier 3 in 1980 and 1981.

77. No wildlife use of this species was noted, and no substantial disease or insect problems were observed. Under the conditions of this experiment, the species was most adapted to areas that were flooded to a depth of 3 ft or less.

78. *Juncus balticus*. Establishment of this species was less than 50 percent on all tiers except Tier 3, where 83 percent of the plants survived the first season (Figure 13). Survival declined on the inundated tiers in 1980, and all plants on the lowest tier died that year. Some plants survived in all plots on Tiers 3 and 4 for the duration of the study, but plants in 25 percent of the plots on Tier 2 died by 1982. Height of plants increased from a maximum of 34 cm the first year to 85 cm in 1982 on Tier 3. Cover ratings followed much the same trend as height, and a maximum cover of 50 to 75 percent was attained on Tier 3 in 1981 and 1982.

79. Plants developed a moderate to severe chlorosis periodically throughout the duration of the experiment and there was widespread necrosis of the culm tips. No wildlife use of the species was apparent.

80. This species is most suited to moist areas and to drawdown zones that do not exceed 1.5 ft. Other species, such as *Carex* species, would provide more cover and probably be more valuable in the zones where *J. balticus* appears to be adapted.

81. *Juncus effusus*. Survival of this species was good to excellent the year of planting, but many plants died during the winter. Maximum survival decreased from 82 percent in 1979 to only 17 percent in 1980 (Figure 14). By July of 1982, there were no surviving plants in

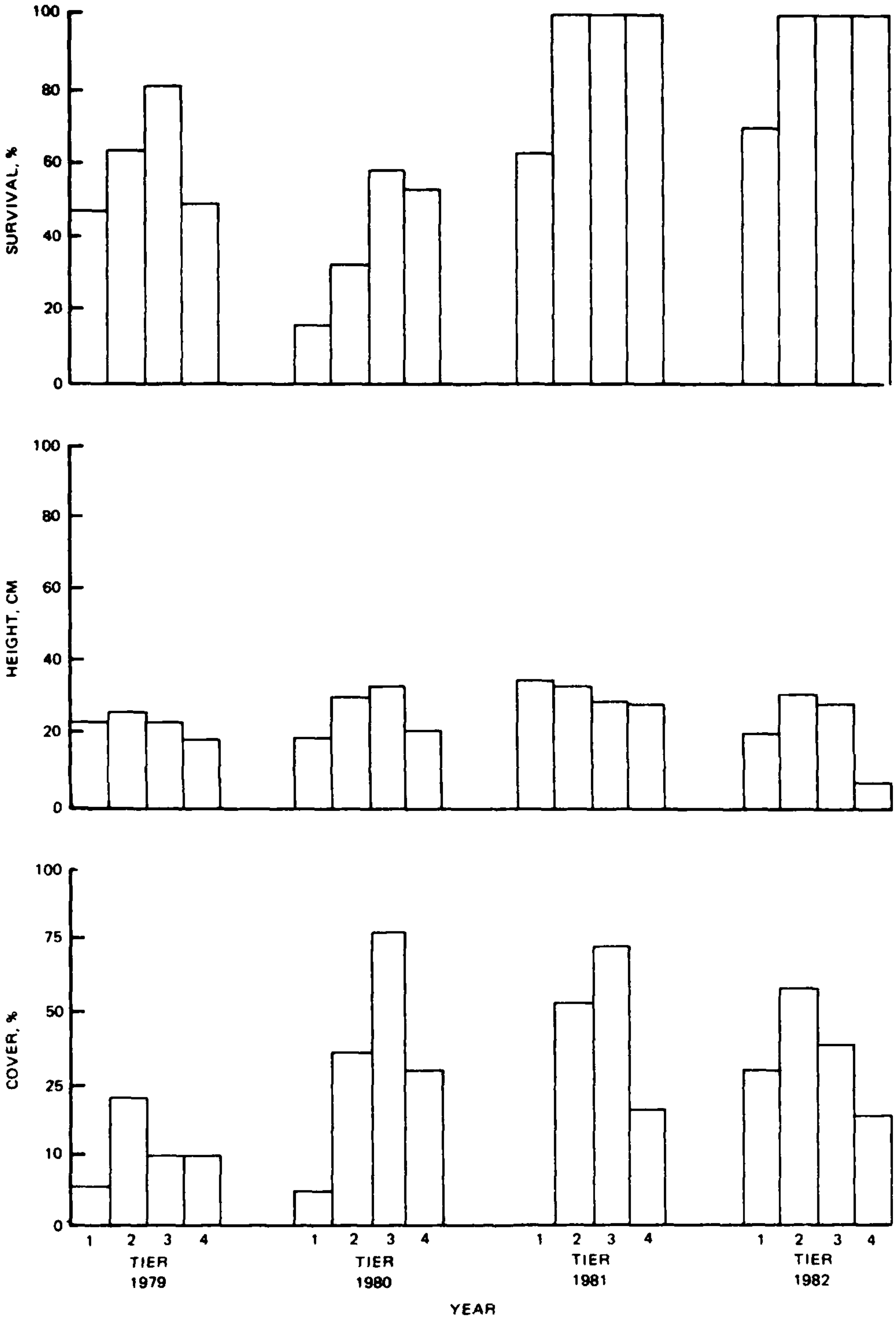

Figure 12. Survival, height, and cover of *Eleocharis palustris* at four flooding depths of the control pool

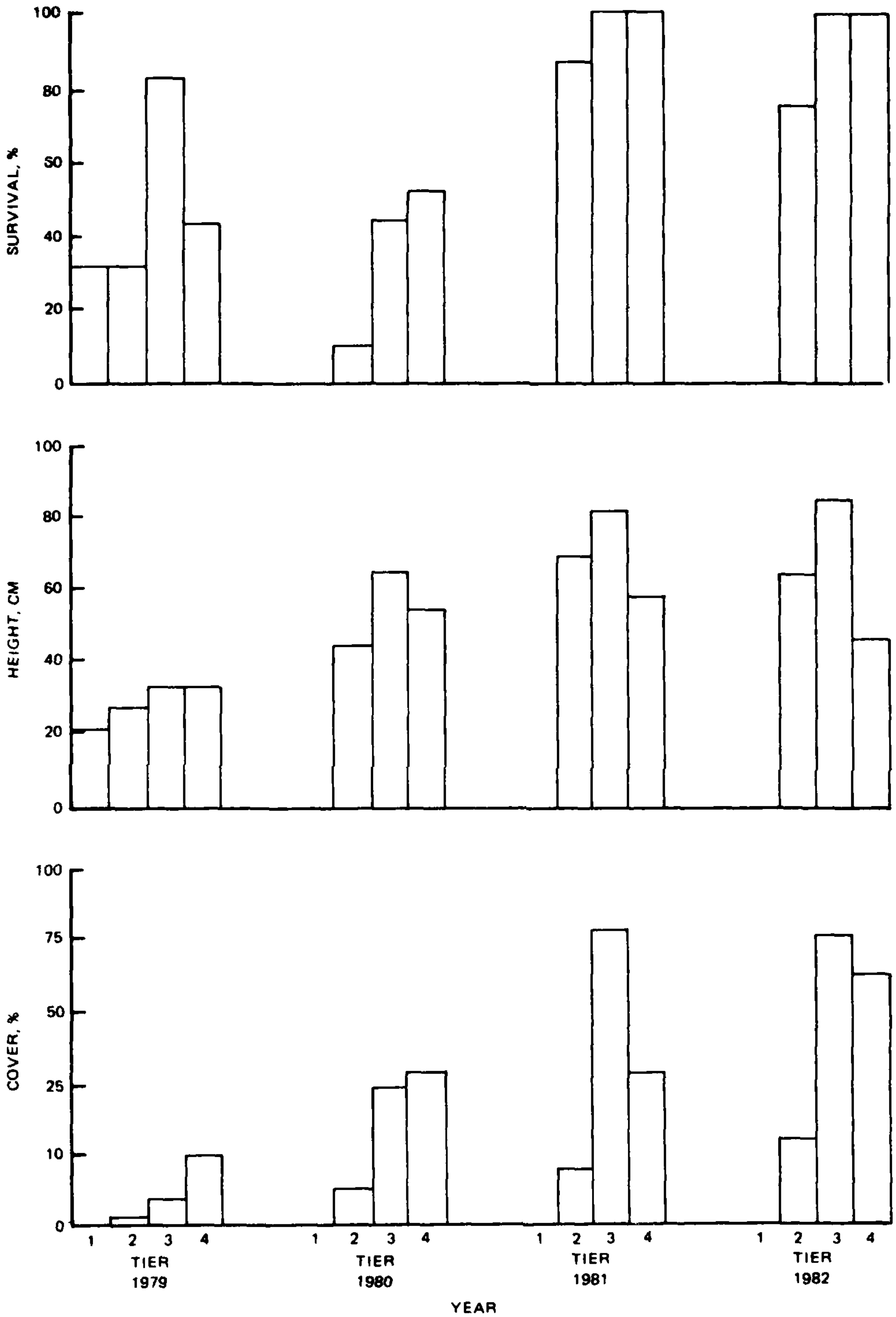

Figure 13. Survival, height, and cover of *Juncus balticus* at four flooding depths at the control pool

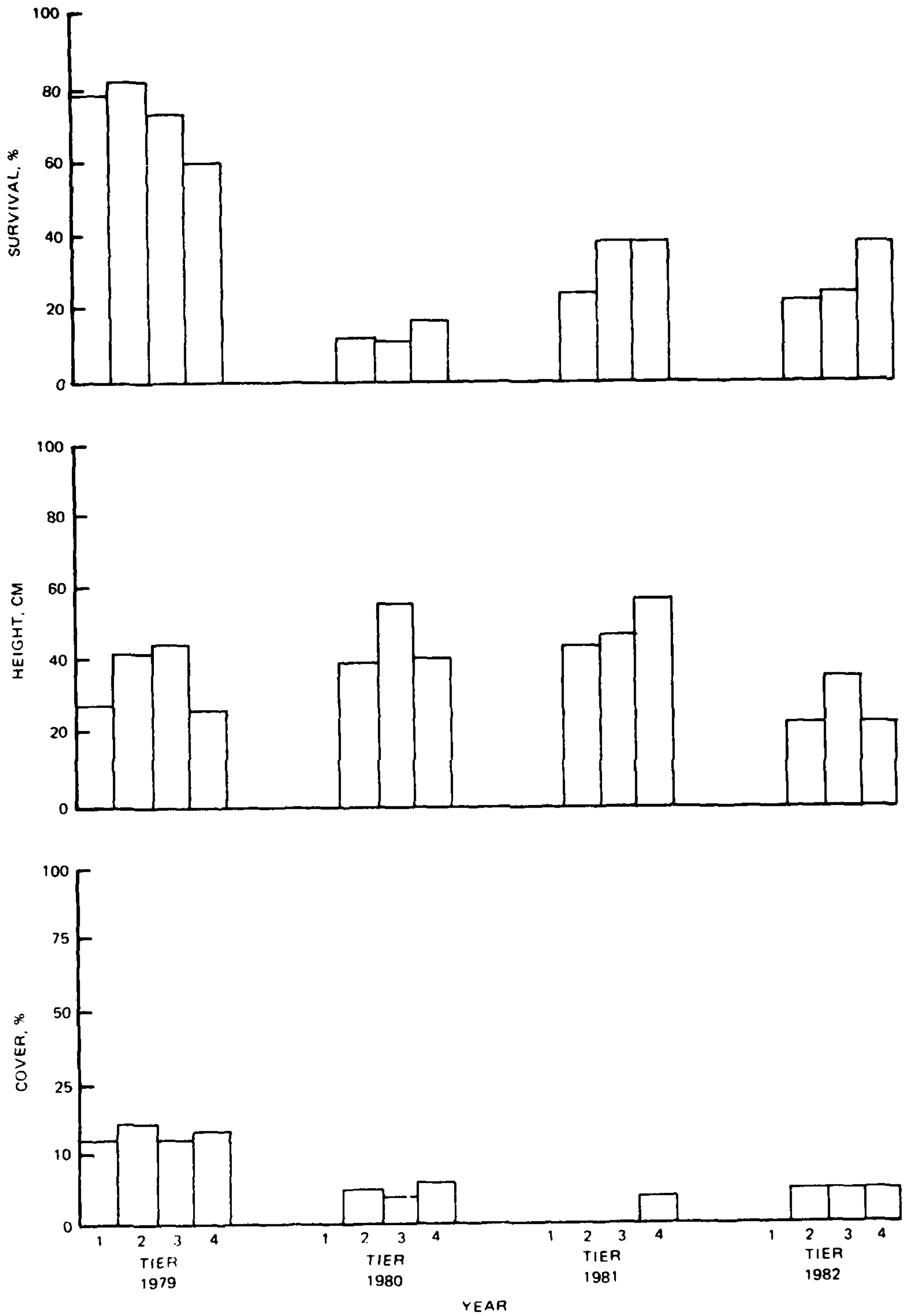

Figure 14. Survival, height, and cover of *Juncus effusus* at four flooding depths at the control pool

75 percent of the plots on Tiers 2 and 3, and all plants on Tier 4 had died. Plants achieved their maximum height of 57 cm in 1980 and 1981 and then declined to 35 cm in 1982. This species grew very slowly and never covered more than 10 percent of the plot area. In 1981, the only cover rating greater than 1 percent was on Tier 4.

82. Plants were moderately to severely chlorotic in 1979 and 1980, but no chlorosis was observed in 1981 and 1982. No wildlife use was noted.

83. The cause for the high first-winter mortality was not apparent, and the overall low survival and slow growth suggest that this species is not well suited to fluctuating environments. Yet, in the mouth of the nearby Umatilla River, a large population of *J. effusus* was observed in the upper reaches of the drawdown zone. This observation suggests that plants on Tier 3 (1.5-ft inundation) should have performed reasonably well. Apparently, some unknown environmental condition was responsible for this discrepancy.

84. *Polygonum persicaria.* This species was planted at the Cold Springs site in June of 1980. One month after planting, 60 percent of the plants were alive, but survival declined throughout the summer and all plants died before winter. Cover never exceeded 25 percent, and maximum plant height was 43 cm.

85. Although this species did not succeed at Cold Springs, it performed well in eight demonstration plots at the control pool. Two plots were planted on each of the four tiers in 1979, and all plants produced flowers and seed. Despite the fact that prevailing winds are from the west and the plots were located on the east levee, numerous seedlings of *P. persicaria* were observed throughout the length of the pool. It was the principal volunteer species on the inundated tiers in 1980. This species continued to reproduce in 1981 and 1982, although its dominance was reduced as other volunteer species became established. Also, in 1982, several *P. persicaria* plants emerged at Cold Springs during an extended drawdown period in June. These plants reached a height of 70 to 80 cm and remained after the site flooded in July.

86. These observations suggest that *P. persicaria* has potential

for use in revegetating drawdown zones in the power production reservoirs of the Columbia River. A drawdown of several weeks duration or more and frequent fluctuation appear to be critical for establishment. The wildlife usage potential for *P. persicaria* has been well documented. Because this species can be economically established from seed, it should be considered for use in revegetation projects.

87. *Sagittaria latifolia.* *Sagittaria* was planted at Cold Springs in 1980. Initial survival (60 percent) and growth (50- to 75-percent cover) were encouraging. Maximum mean height (51 cm) occurred on Tier 2. No other herbaceous species at any site achieved 50- to 75-percent cover in the first season's growth. Rhizome growth extending outside the plots was also excellent.

88. This species survived through the fall and senesced early after having 100 percent of its leaf blades grazed by waterfowl. Overwinter survival was assumed for all plots. At the end of April 1981, all plots had been extirpated by wildlife (either waterfowl or muskrats). This extirpation included the experimental plot and the surrounding tuber growth. Plants within plots did not recover, but tubers on the periphery of the colony survived. Survival and growth of *S. latifolia* declined during the remainder of the experiment; there was less than 1-percent cover in 1982.

89. Wildlife usage continued through 1981 and 1982 but was confined to grazing of the foliage rather than extirpation of the tubers and rhizomes.

90. Because of the wildlife use potential of this species and its initial growth rate, both in 1980 and in another experiment (see section "Transplant Performance - Cold Springs"), this species should be considered for revegetation of areas where the leaf blades are exposed to the atmosphere at high pool. In the McNary pool, this would be at elevations of approximately 337.5 ft and above. Because of its attractiveness to waterfowl and other wildlife, sufficient numbers should be planted to ensure survival.

91. *Scirpus americanus.* Survival of this species was more than 90 percent on all tiers in 1979. However, during the winter, all plants

on Tiers 1 and 2 died and only 45 percent of the plants on Tier 3 survived (Figure 15). Maximum plant height (45 cm) was attained in 1980, and height declined each year thereafter. Cover percentages followed the same trend as plant height, with a maximum of 50 to 75 percent on Tier 4 in 1980.

92. In the fall of 1980, muskrats entirely extirpated all eight plots of *S. americanus* on Tier 3, as well as rhizomes that had invaded adjacent plots. The species recovered very slowly from this usage in plots where one or more rhizomes survived. In 1981, muskrats again entered the plots, but were removed (trapped) before they could do extensive damage. In 1980, muskrats restricted their activity to the inundated tiers; in 1981 they were active in noninundated (Tier 4) plots, but were either unable to dig in the more compact soil or were removed before they had extirpated the plants.

93. Aside from the feeding activity of muskrats, no other wildlife appeared to use *S. americanus*. Surviving plants developed a general culm tip necrosis and were moderately to severely chlorotic each year.

94. This species is probably not suited for deep zones, but may be useful in the upper drawdown zone and along the shoreline. Further research is needed to identify planting conditions or methods that will prevent extirpation by muskrats.

95. *Scirpus validus.* Eighty-nine to 95 percent of the plants survived on all tiers during the season of planting, but mortality was high during the 1979-1980 winter. Populations within the plots never completely recovered, and at least 25 percent of the plots on inundated tiers contained no live plants in 1982. All plants on Tier 1 had died by 1982 (Figure 16). The cover values for *S. validus* remained between 10 and 25 percent, but this does not adequately reflect its performance on Tiers 2 and 3. The species did not perform well on the noninundated tier even though the data for the three upper tiers are similar. Plants on Tiers 2 and 3 grew mostly outside the plots and were repeatedly cut back to prevent them from invading adjacent plots. Meanwhile, the original or older culms died. As the rhizomes recovered, they would grow

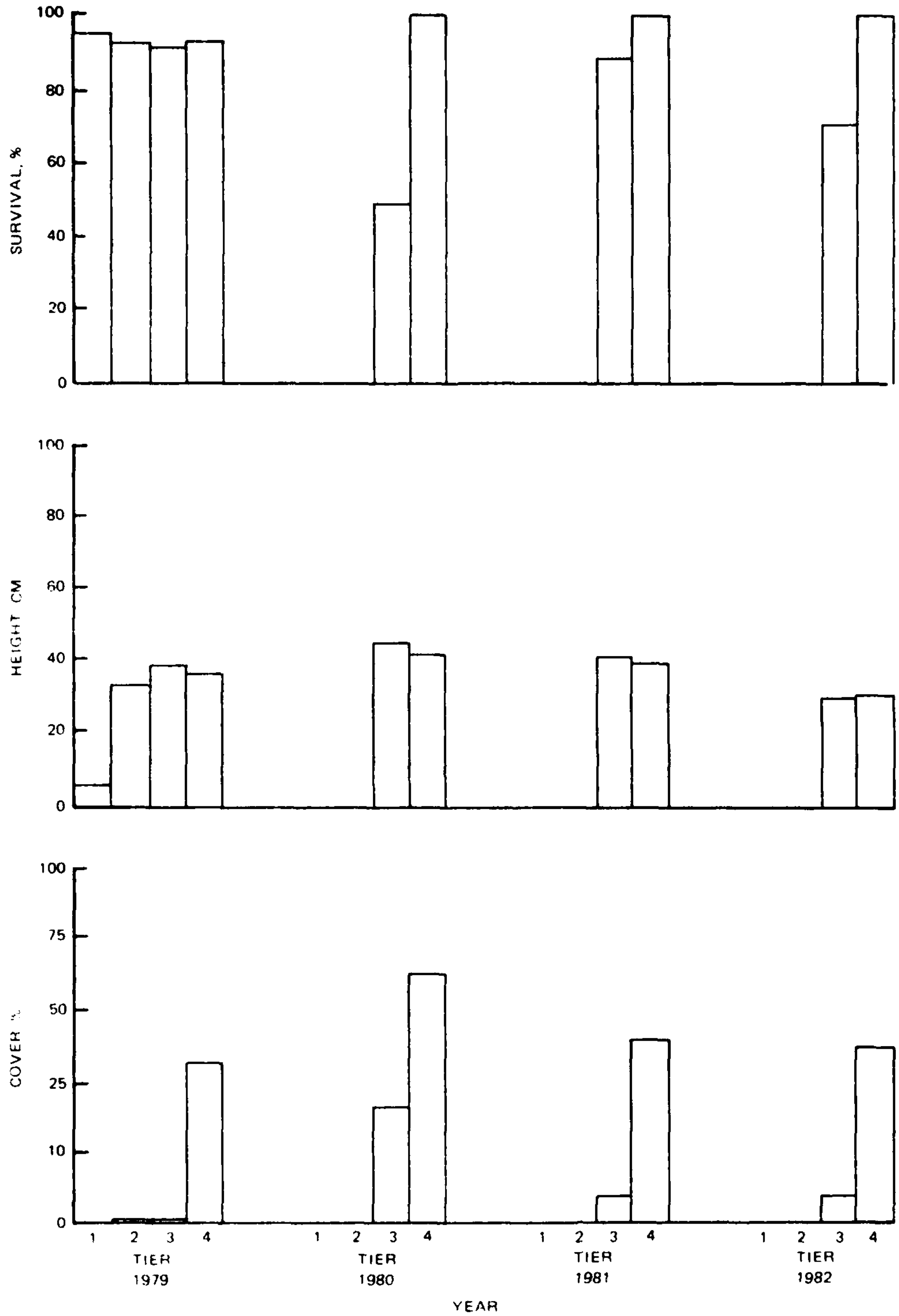

Figure 15. Survival, height, and cover of *Scirpus americanus* at four flooding depths at the control pool

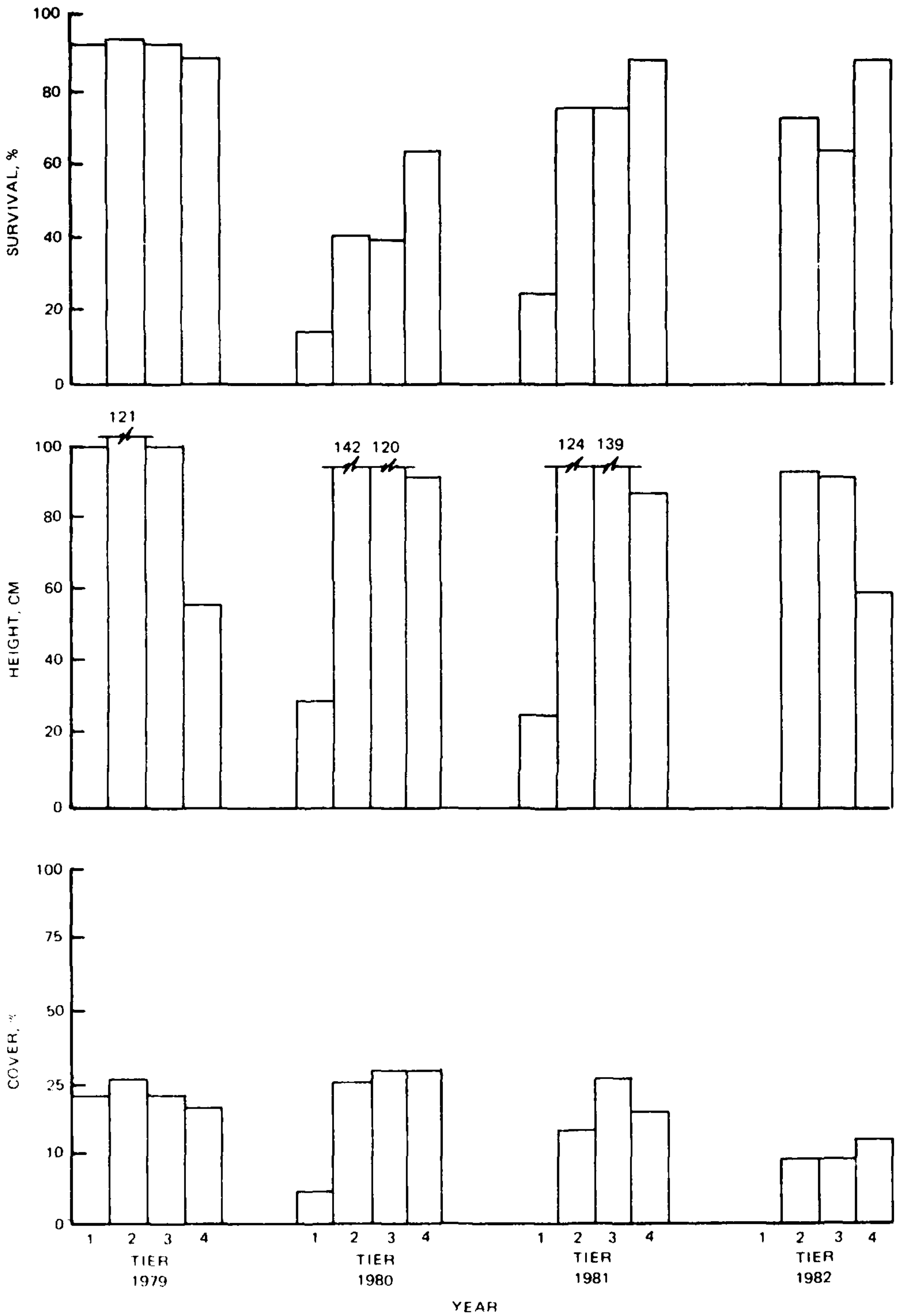

Figure 16. Survival, height, and cover of *Scirpus validus* at four flooding depths at the control pool

toward the outside of the plot. If they started within the plot, they soon grew out the other side of the narrow plots and were again severed. This was the tallest herbaceous species in the experiment. Height appeared to be related to flooding depth within the range of 0 to 3 ft. Maximum height (142 cm) was on Tier 2 in 1980; height of plants on Tier 4 was only 90 cm.

96. *Scirpus validus* was affected from the first season by a chronic fungal disease that varied in intensity from year to year. The causal organism was not identified. Muskrats occasionally cut culms of *S. validus* but did not devastate any plots.

97. Because *Scirpus validus* was the only species from the 1979 planting that survived for the duration of the experiment at Cold Springs, it is the leading candidate for use in shoreline revegetation. It should be noted that the surviving plants of this species at Cold Springs were either in the protected wind shadow of a nearby island or near the shoreline where wave action was less severe.

98. Muskrats occasionally used this species for lodges and, in 1981, constructed a lodge within a plot on Tier 3.

99. *Trifolium wormskjoldii*. Initial survival of this species ranged from 82 to 96 percent on the four tiers. However, by mid-1980 nearly all plants on Tier [illegible] were dead, and survival on Tier 2 was only 40 percent (Figure [illegible]). All plants on Tier 1 eventually died. Those remaining on Tier 2 [illegible] they produced little growth as reflected in cover ratings. [illegible] inundated plots eventually declined to below 1-percent cover. [illegible] values on the noninundated tier (Tier 4) declined due to wildlife feeding. Mean maximum plant height was 4.5 cm on Tier 3 in 1980 and [illegible].

100. Occasional chlorosis occurred sporadically throughout the plots and was the only disease symptom observed. Gophers, rabbits, and hares had a substantial impact on the growth of plants on Tier 4. The feeding activity of these mammals was responsible for the decrease in survival and cover value on Tier 4. From 1979 through 1981, no feeding on inundated plots was observed. However, in 1982, plots on Tier 3 were grazed by rabbits.

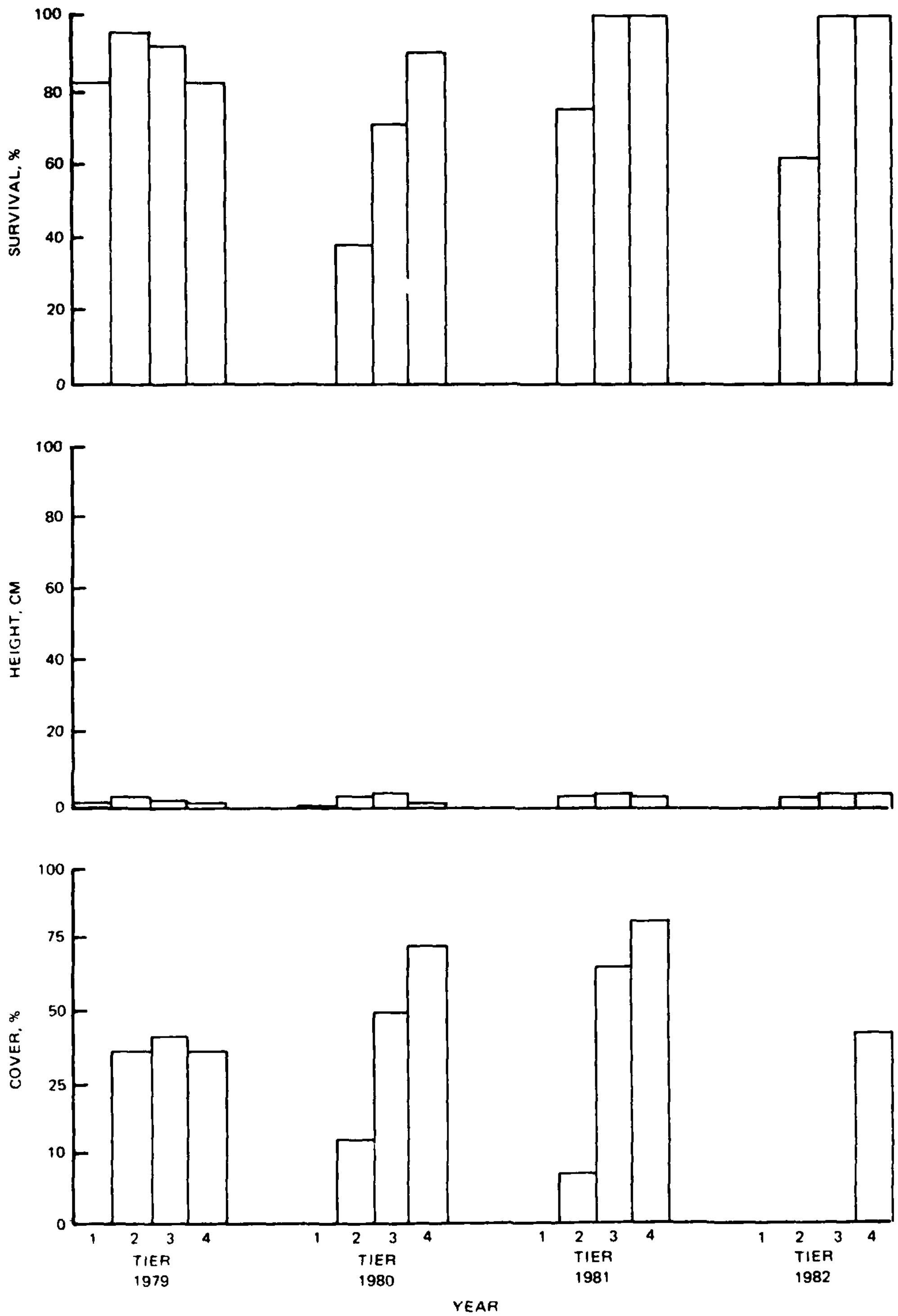

Figure 17. Survival, height, and cover of *Trifolium wormskjoldii* at four flooding depths at the control pool

101. This species is not suitable for use in drawdown zones, although it might be useful in moist upland habitats.

102. *Typha latifolia.* Initial survival of this species ranged from 59 percent on Tier 4 to 80 percent on Tier 3 (Figure 18). The first year, overwintering mortality was extremely high. All plants on Tier 1 died by mid-1980 and at least 75 percent of the plants on other tiers succumbed. Survival continued to decline throughout the experiment. Stunted, chlorotic plants characterized this species at the test pool. Cover did not exceed 10 percent on any tier during the study. Maximum height (100 cm) occurred on Tier 2 in 1980. This species grows prolifically in marshes of the area. It appears likely that the high pH of the soil was principally responsible for the poor performance of this species at the control pool.

103. Wildlife did not use this species at the control pool. Although this species grew well on Tier 3 at Cold Springs, muskrats cut the new shoots off several centimetres above the soil surface in the spring of 1980. The cut stems and high water combined to kill the plants at Cold Springs.

104. The survival and growth of this species at the control pool suggest it is not suitable for revegetation of the drawdown zone. However, its natural occurrence near the Cold Springs site and in many other areas is evidence that it is a potentially usable species, at least in the upper portion of the drawdown zone.

Woody species

105. *Cornus stolonifera.* *Cornus* saplings that had not broken dormancy were planted at the control pool in 1980. More than 95 percent of the plants became established on all tiers (Figure 19). Treatment effects became apparent in 1981 and were more pronounced in 1982. There was a distinct demarcation between plants on the second tier. Plants on the upper slope of this tier were normal while those on the lower portion of the tier appeared to be stressed, having small, malformed leaves. Survival remained relatively steady on the upper three tiers through 1982, but decreased from 96 to 57 percent on the lowest tier (Tier 1).

106. Plants on Tier 1 and 2 did not grow as rapidly as those on

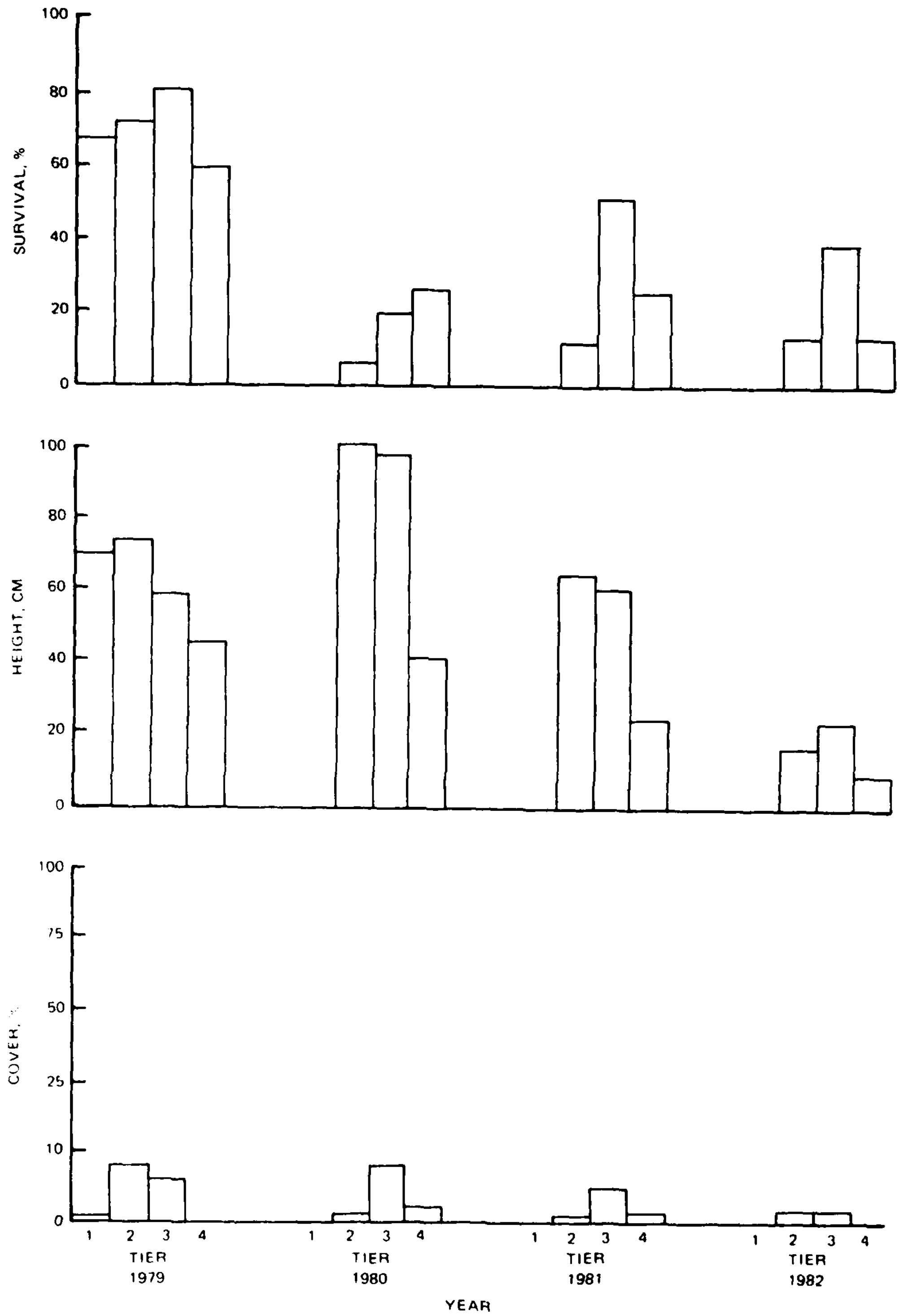

Figure 18. Survival, height, and cover of *Typha latifolia* at four flooding depths at the control pool

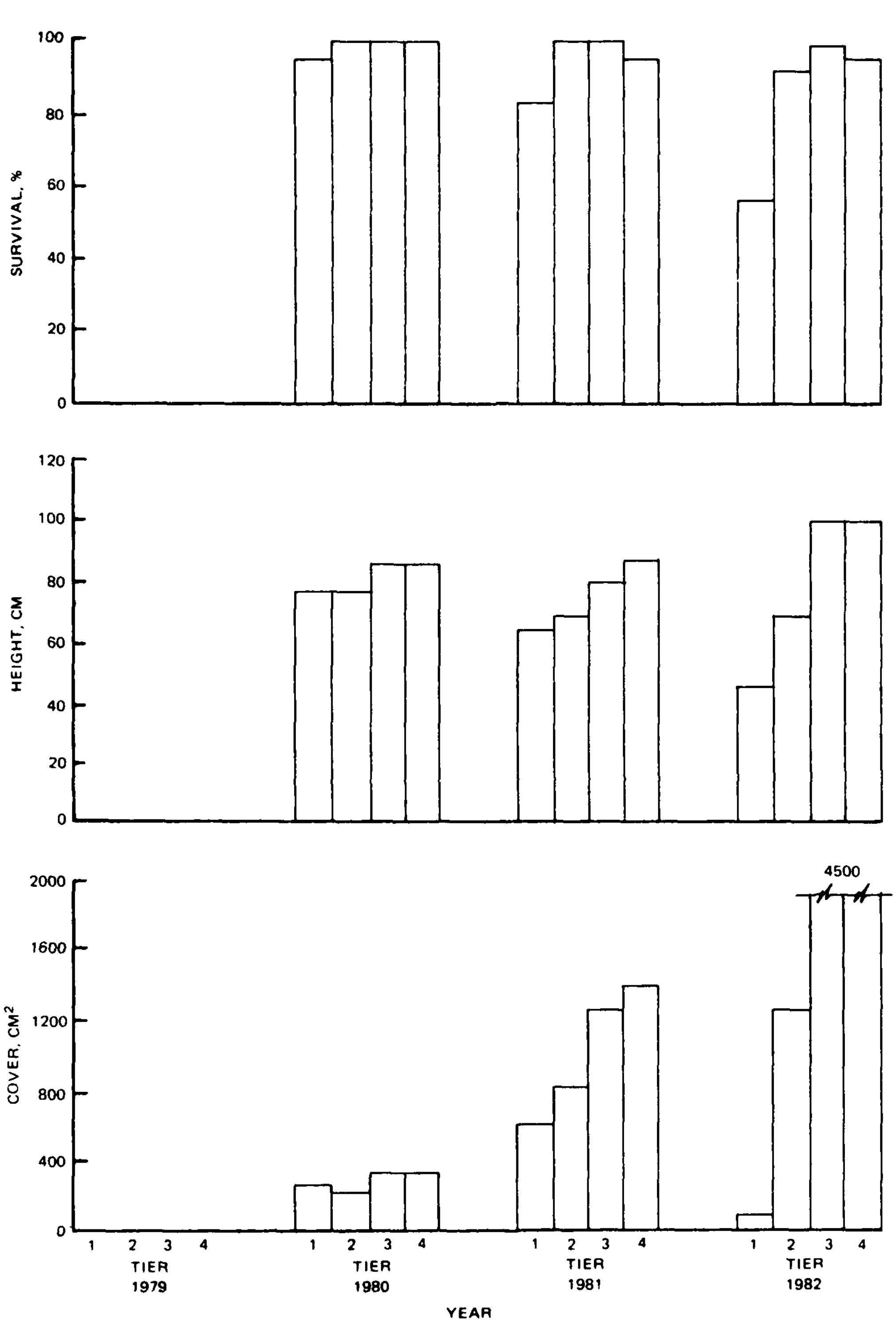

Figure 19. Survival, height, and cover of *Cornus stolonifera* at four flooding depths at the control pool

Tiers 3 and 4. Cover actually decreased on Tier 1 between 1981 and 1982. Average cover of plants on Tiers 3 and 4 in mid-1982 was 4,500 cm^2/plot.

107. *C. stolonifera* is a slow-growing species, and plant height did not increase appreciably during three growing seasons, even on tiers where survival was good. Maximum height increase during the study was only 17 cm (Tiers 3 and 4).

108. Deer were the only wildlife that were documented as using this species. They browsed it during the winters of 1980 and 1981.

109. *C. stolonifera* is most suited for use along the margin of reservoirs where water depth does not exceed 1.5 to 2 ft. It is a shade-tolerant species and did not grow well on Tiers 3 and 4 where it was exposed to full sunlight. Where this species was partially or fully shaded, the plants had much larger leaves and grew taller. This would indicate that the species might establish and grow best if planting were postponed until other pioneer species had established themselves such that they could shade *Cornus* plantings.

110. *Elaeagnus angustifolia*. The first-year establishment averaged 52 percent, but the first winter eliminated the species from the lowest two tiers (Figure 20). Survival on the third tier declined from 58 to 17 percent during the first winter and continued to decline until the termination of the experiment (Figure 20). On the noninundated tier, survival remained relatively constant at about 50 percent during the study. Plants on the third tier grew very slowly, and their height remained under 1 m. Plants on the noninundated tier (Tier 4) grew very well and attained a mean maximum height of 4.6 m. Area covered by this species was minimal on Tier 3, but doubled each year on Tier 4 until 32 m^2 (nearly 10 times the actual plot area) was covered in 1982.

111. This species flowered profusely in 1982 and produced a large crop of fruit. Small songbirds were often seen on the floor of the plots searching through fallen leaves. These plots also provided cover for rabbits (eastern cottontail) that frequented the pond.

112. This species is not suited for use in the drawdown zone, but it is suitable for moist, upland sites. In this area, many ranchers consider the species a weed because its growth and the thorns it produces

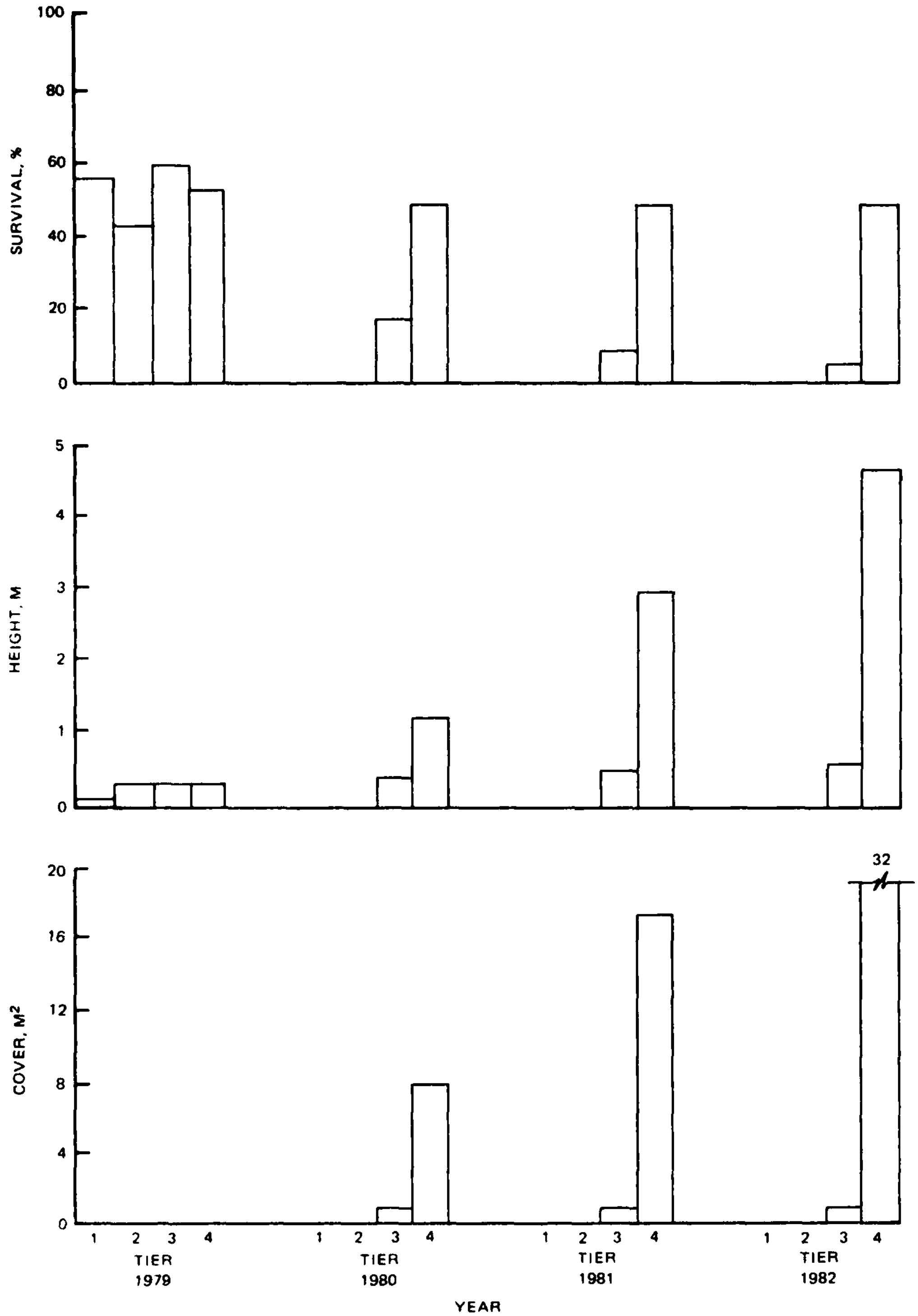

Figure 20. Survival, height, and cover of *Elaeagnus angustifolia* at four flooding depths at the control pool

can prevent cattle from using watercourses. In addition to abundant seed production, which can become a nuisance in irrigation systems by plugging nozzles, the plants reproduce vegetatively by shoots from root systems. Several check plots on Tier 4 were invaded and completely taken over by growth of this nature. Because of its potential as a weed species and its dense population in some areas, cautious consideration should precede its selection for use in revegetation projects.

113. *Morus alba.* Survival of *M. alba* ranged from 72 to 95 percent during the year of establishment, but by midsummer of 1980, no more than 8 percent of the plants on Tiers 1 and 2 were alive (Figure 21). Survival decreased gradually on the upper two tiers and, by 1982, survival on Tiers 3 and 4 was 37 and 67 percent, respectively. Plant growth was slow, and the plants never coalesced as did several other species. Height of plants on the upper two tiers increased annually to a maximum of 116 and 131 cm on Tiers 3 and 4, respectively. The area covered by the plants reached a peak in 1981 of 3 m^2 per plot on Tier 4. Survival and growth suffered not only from the treatment, but from wildlife usage and nutrient deficiency as well. The principal wildlife damage was caused by gophers that eliminated almost two entire plots on Tier 4 in 1980. Although deer browsed this species, as they did almost all woody species, they did not cause considerable damage. Chronic chlorosis appeared early in the first year and continued throughout the duration of the experiment. The symptom suggested iron deficiency. The severity of the symptoms suggests that this was one of the primary causes for limited plant growth.

114. The data indicate that this species is not suited for use in the lower drawdown zone of reservoirs. It might be used in shallow waters with longer or more frequent drawdowns and on the margin of reservoirs. A volunteer plant on Bobbie's Beach produced tremendous growth in the four summers of this experiment. The planted specimens did not produce as much growth but did grow taller than most specimens at the control pool.

115. *Ribes aureum.* Performance of this species was very poor on all tiers. Less than 15 percent of the plants survived the first year,

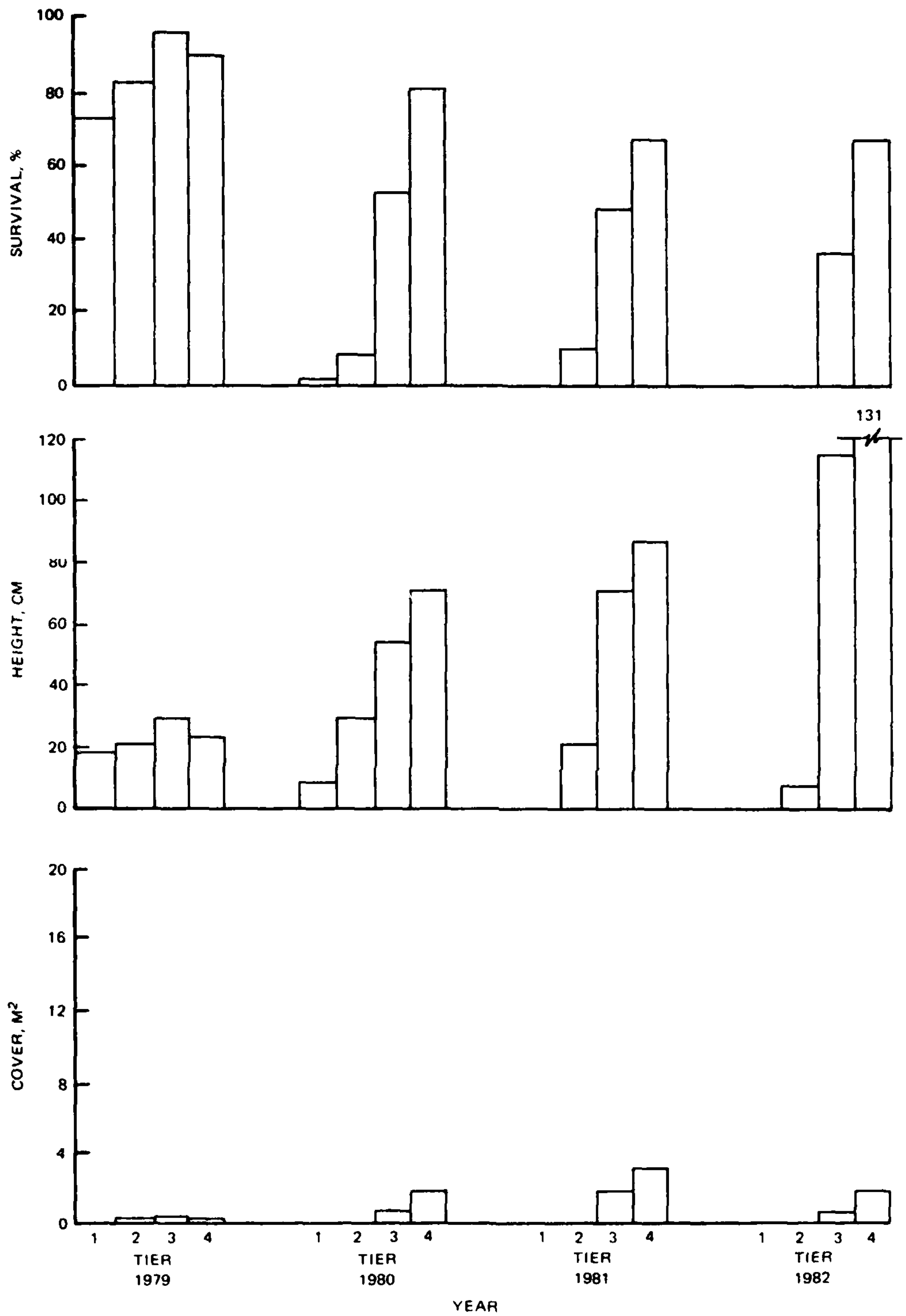

Figure 21. Survival, height, and cover of *Morus alba* at four flooding depths at the control pool

and this diminished to 3 percent by 1982 (Figure 22). No plants survived on Tiers 1 and 2. Growth, in terms of both height and cover, was small and declined between 1981 and 1982. Height never exceeded 50 cm, and cover was less than 0.5 m^2 throughout the study.

116. Wildlife and insects did not appreciably damage *Ribes*, although it was infested in 1981 and 1982 with aphids. Downward growth of leaves was observed soon after the aphids appeared, but growth returned to normal when the infestation ended.

117. The survival and cover data indicate that this species is not suitable for use in revegetation of drawdown zones or upland habitats under the conditions of this experiment.

118. *Robinia pseudoacacia*. *Robinia* survival during the year of planting was poor; about two-thirds of the plants died that year. The first year overwinter mortality was 100 percent on all inundated tiers. Plants on the fourth tier remained small during 1980, but in 1981 they began rapid height growth (Figure 23). The data summarized in Figure 23 do not represent the true height that this species achieved in the plots where it survived. Because the summaries are numerical averages and not all the plots contained plants, the mean height of the surviving plants is not fairly represented. Plants that survived reached a height of 4 to 5 m. Cover increased dramatically on Tier 4 in 1981 and continued to increase in 1982, although at a slower rate. In July 1982, cover averaged 13.5 m^2/plot.

119. These data show that this species is unsuited for use in the drawdown zones but that it might be useful in moist to dry upland habitats.

120. *Rosa multiflora*. Initial survival of *Rosa* ranged from 40 to 57 percent on the four tiers. Plants on the lowest tier succumbed in 1980, and survival declined on the remaining inundated tiers (Figure 24). In 1981, survival stabilized, but only about 30 percent of the plants survived on Tiers 2 and 3. Growth was slow during 1979 and 1980, but in the final 2 years, cover increased substantially on Tiers 3 and 4. Area covered by plants on both of these tiers was slightly more than 13 m^2 in

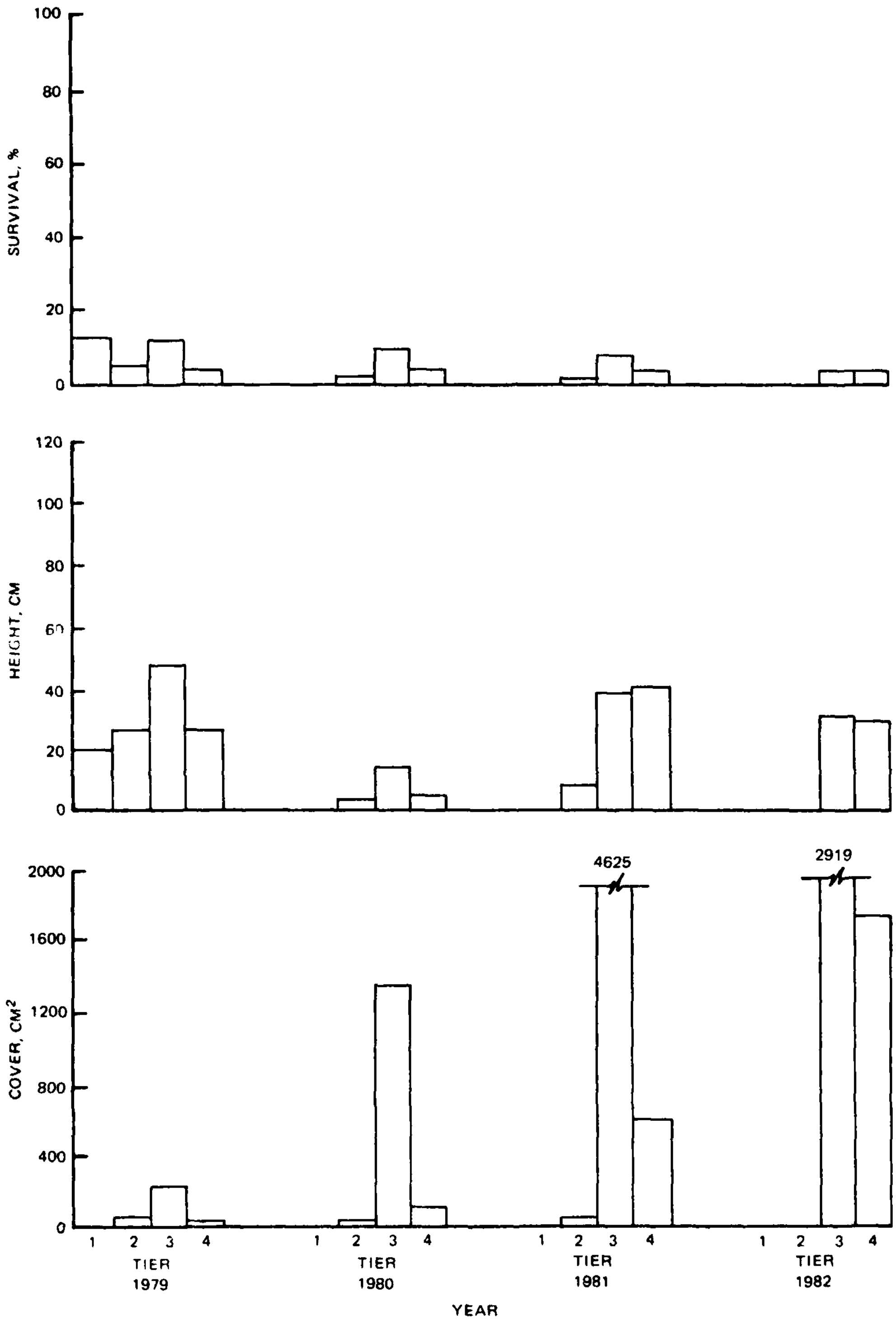

Figure 22. Survival, height, and cover of *Ribes aureum* at four flooding depths at the control pool

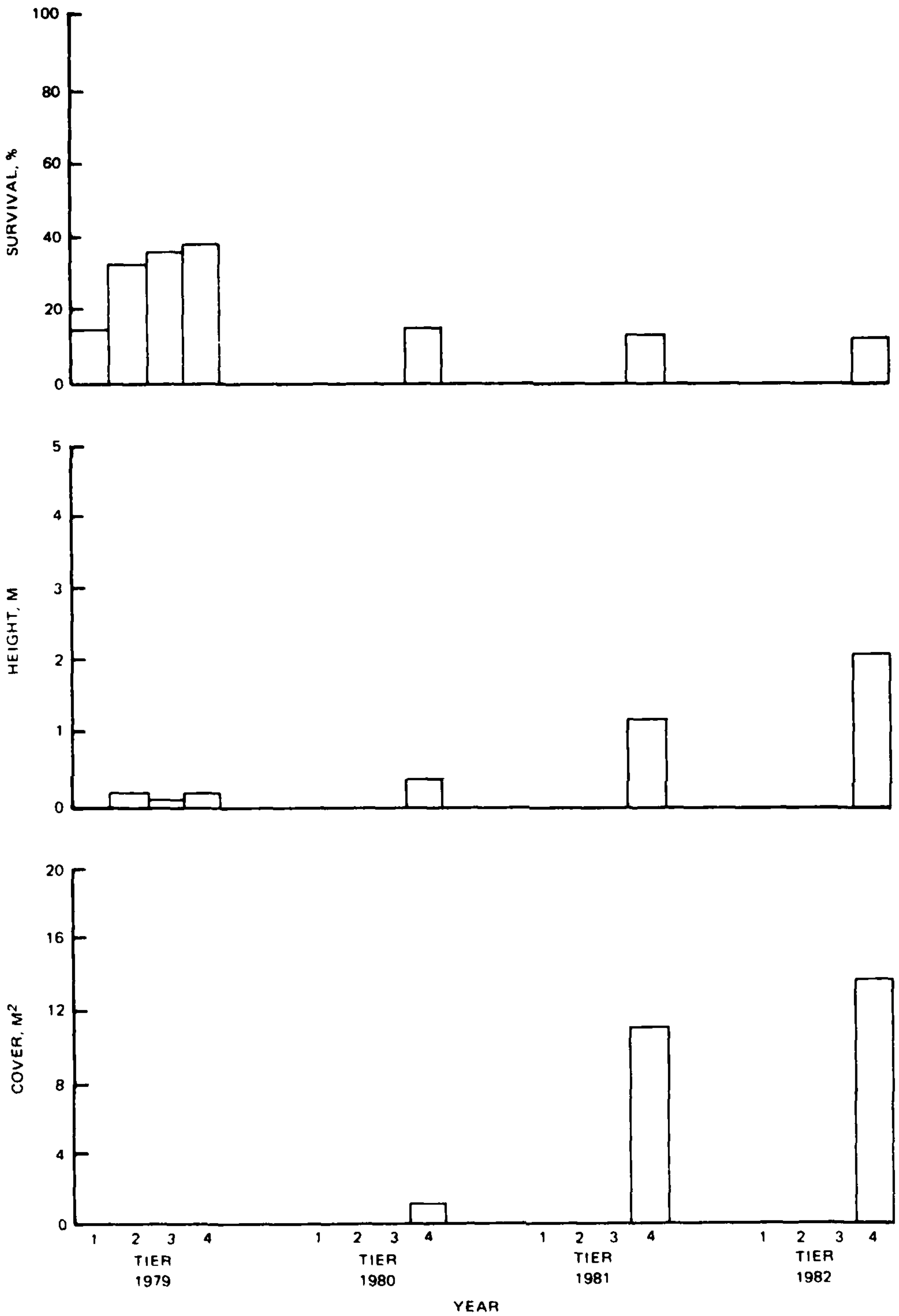

Figure 23. Survival, height, and cover of *Robinia pseudoacacia* at four flooding depths at the control pool

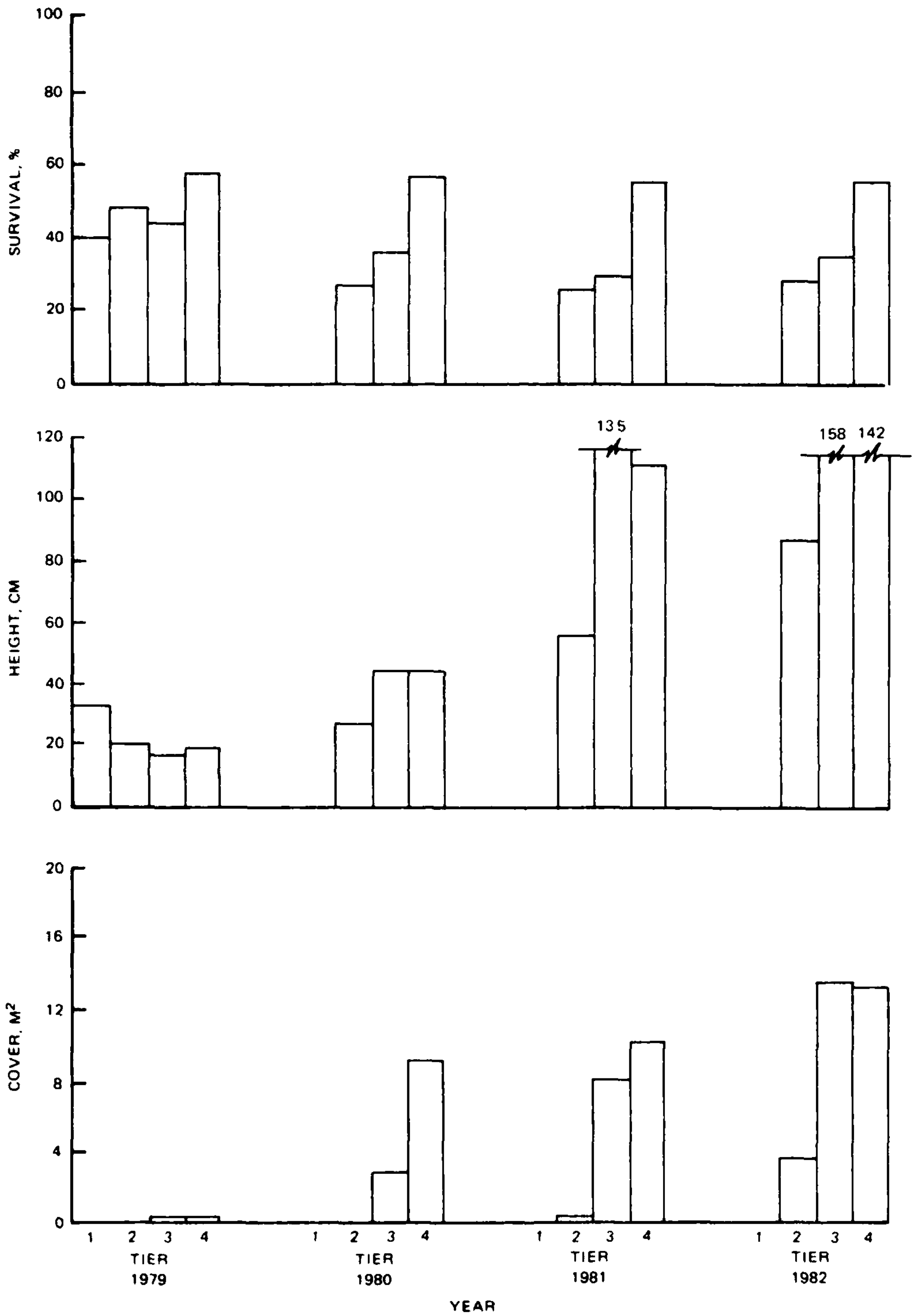

Figure 24. Survival, height, and cover of *Rosa multiflora* at four flooding depths at the control pool

1982, even though there were nearly twice as many live plants on Tier 4 as on Tier 3.

121. Height of plants on Tiers 3 and 4 reached a maximum of about 1.5 m in 1982. Wildlife such as rabbits, quail, and pheasant used this cover. *Rosa* displayed mild to severe chlorosis sporadically. The symptoms were more widespread and severe in the first 2 years of the experiment. In 1981, two plots were attacked by downy mildew, but the plants recovered in 1982.

122. *Salix fragilis.* Survival of this species was good to excellent (69 to 96 percent) on all tiers during the first year of establishment. In 1980, survival on the first tier decreased to 50 percent, but few plants died on other tiers. The number of live plants remained relatively constant on all but Tier 2 after 1980 (Figure 25).

123. Growth of this species, as indicated by height and cover, was excellent, especially on Tiers 3 and 4. Height and cover increased each year on every tier, being most rapid on Tier 3 and slowest on Tier 1. Cover in 1982 ranged from 2.5 m^2 on Tier 1 to 34 m^2 on Tier 3; maximum height was 5 m.

124. Wildlife used this species for both cover and food. Deer browsed on it the first two winters, and songbirds and rabbits used the foliage for cover. Muskrats occasionally removed small branches, and beaver cut substantial amounts of *S. fragilis* at Cold Springs and Bobbie's Beach. Insect populations became high enough each year, except 1979, to warrant control. The first year, populations of mourning cloak butterfly and cottonwood beetle larvae required control measures. During the summer of 1981, tent caterpillars were controlled, and in the fall, a massive aphid infestation was controlled. The mourning cloak butterfly larvae and larvae of cottonwood beetle returned but did not become numerous enough to justify control.

125. Disease did not become a problem until 1982. The species did not show the chlorosis displayed by several herbaceous species and *Morus alba*, although two trees in a single plot on the second tier died suddenly in 1981. The cause was not determined, and no other plants appeared affected that year. In the spring of 1982, a widespread

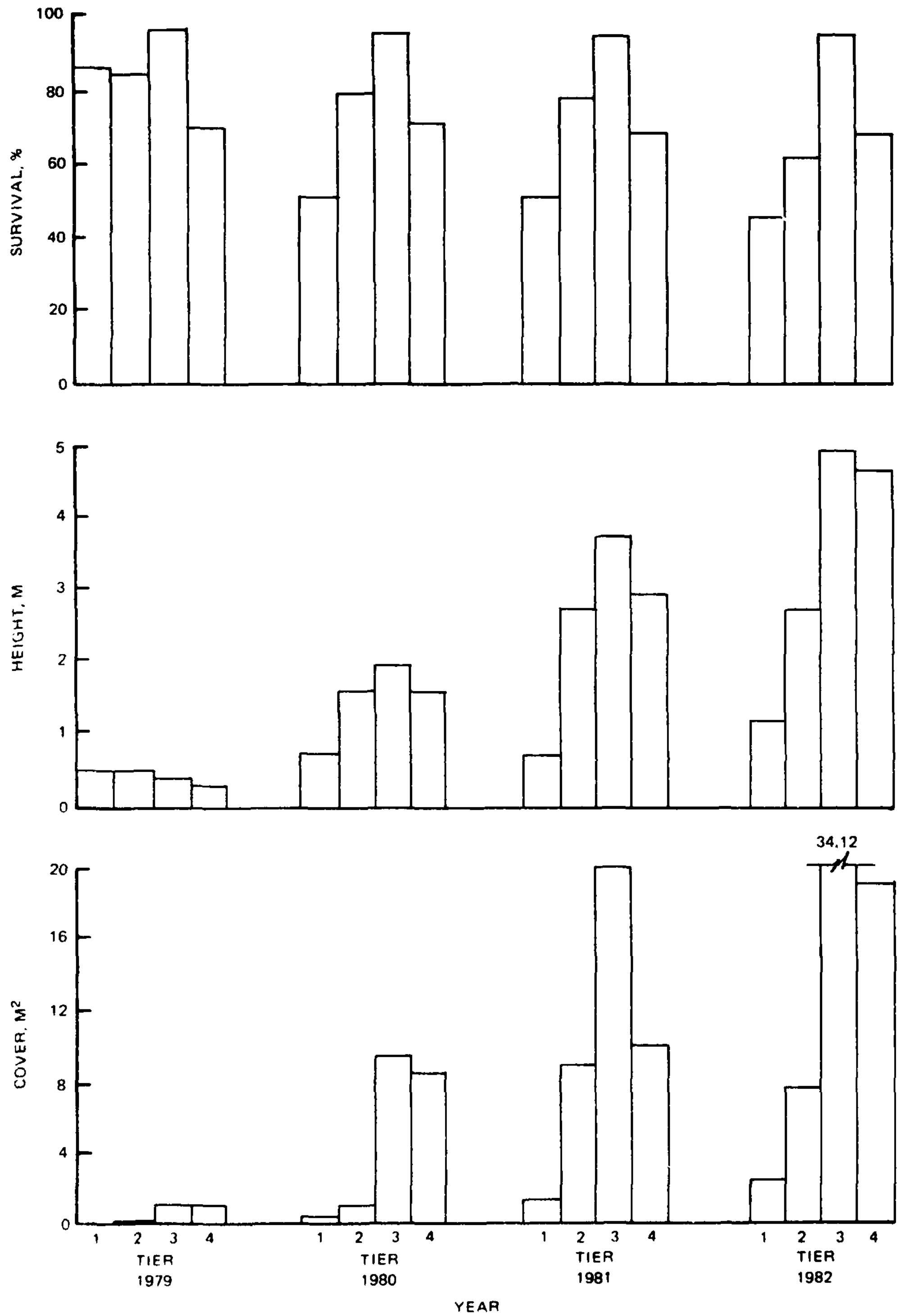

Figure 25. Survival, height, and cover of *Salix fragilis* at four flooding depths at the control pool

abscission of leaves was followed by necrosis of the branch and eventual death of the tree. Plant pathologists ruled out a pathological causal agent, so the symptoms are likely the result of a physiological disorder brought on by treatment, nutrient deficiency, salinity, pH, or perhaps a combination of these.

126. These data indicate that *S. fragilis* is suitable for the entire drawdown zone (4.5 ft) and for noninundated shorelines. Work at the Cold Springs site (see "Transplant Performance - Cold Springs") suggests that cuttings of this species for planting should be tall enough to permit some foliage to protrude into the atmosphere during high pool, especially when drawdowns are infrequent. Cuttings should be planted in sufficient numbers to withstand feeding pressure from beaver, and planting techniques or protective measures that prevent ice damage should be employed.

127. *Salix lasiandra*. Fifty-eight to 70 percent of the plants became established the first year (Figure 26), but survival decreased gradually during the remainder of the experiment. Best survival was on Tier 3 (45 percent in 1982). Growth, as measured by cover and height, increased each year on all tiers except for the first, where it remained stable. Maximum plant height (3.9 m) and cover (23 m^2) were achieved on Tier 3 in 1982.

128. Birds and small mammals used *S. lasiandra* for cover. Deer lightly browsed this species each winter. In 1981, a moderate infestation of tent caterpillars was controlled; otherwise, the species was not substantially affected by insects.

129. Mild to moderate chronic chlorosis occurred on Tier 4, and these plants appeared stunted.

130. The source material for the plants used in this experiment came from the Blue River Reservoir in central Oregon on the west side of the Cascades. The parent material receives a maximum of 45 ft of inundation each year, usually during the summer. Therefore, the parent material has shown the potential to withstand deep, prolonged flooding. However, this study did not document such a degree of flood tolerance using transplants. It indicated only that this species should perform

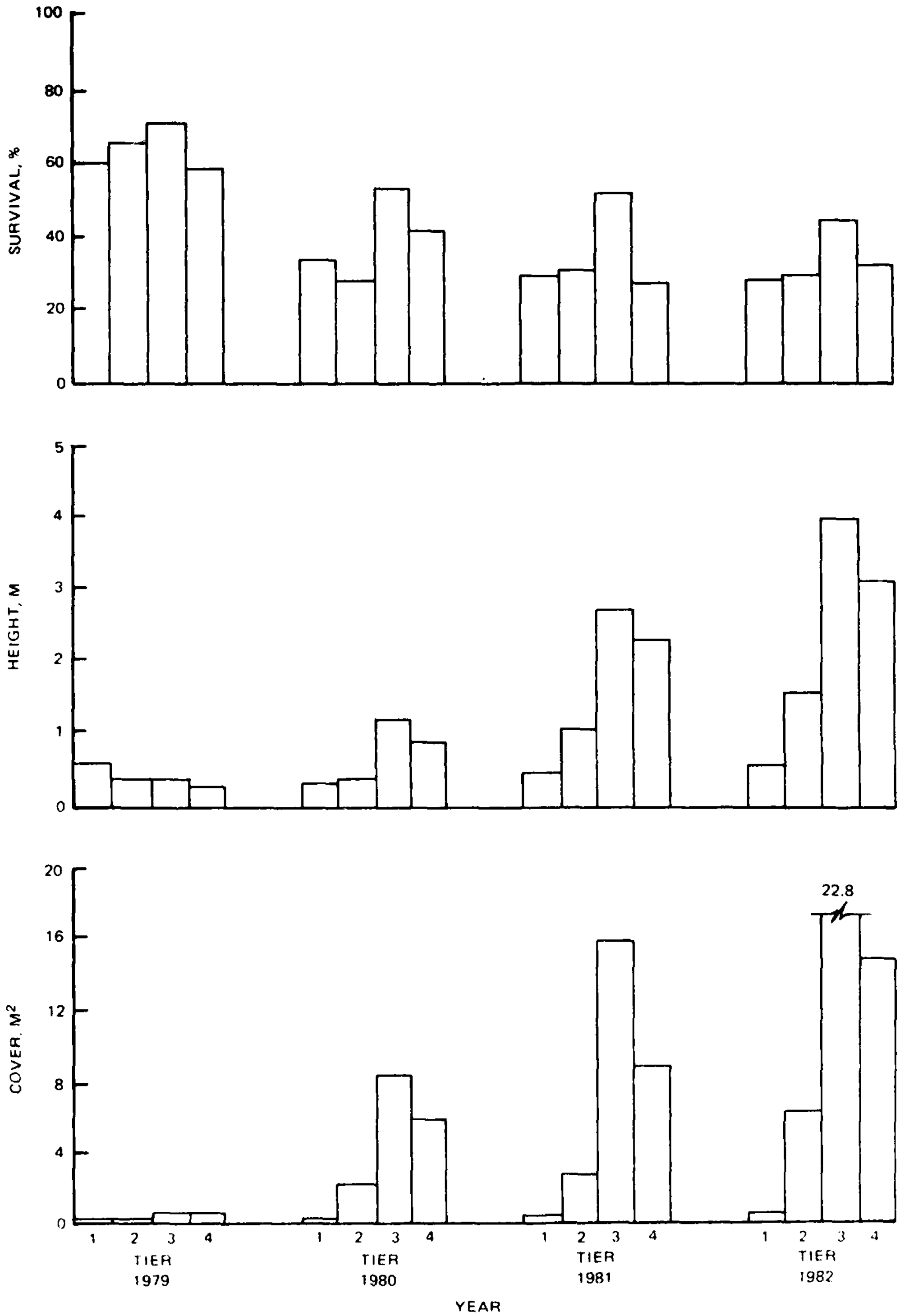

Figure 26. Survival, height, and cover of *Salix lasiandra* at four flooding depths at the control pool

satisfactorily in drawdown zones where the water does not exceed about 3 ft at high pool.

131. Salix purpurea var. nana. Initial survival of *S. purpurea* ranged from 60 percent on Tier 1 to 4 percent on Tier 4 (Figure 27). About one-third of the plants on Tier 1 died the first winter, but plant populations on other tiers remained stable. Thereafter, there was no further mortality and plants grew well. Plant height and cover increased gradually during the study on every tier. Maximum plant height (172 cm) was on Tier 3 in 1982. Plant height was influenced by the shrubby growth habit, as compared with the tree growth habit of *S. fragilis* and *S. lasiandra*. This was the first species to coalesce, probably also because of its growth habit. Areal cover of this species at the end of the study ranged from 4 m^2 on Tier 1 to 18 m^2 on Tier 3.

132. Wildlife used this species for cover and food. In 1981, a muskrat started to build a lodge on Tier 3. Pheasants, quail, songbirds, rabbits, and mink used this species for cover. All the plots of *S. purpurea* planted in 1980 at Cold Springs were harvested by beaver. Deer occasionally browsed this plant. Insects did not damage this species, and only in 1982 was a mild chlorosis observed in the leaves of plants on Tier 4.

133. If it were not for the initially low survival rate of this species, *S. purpurea* could well be the best woody species evaluated. The low survival rate probably is largely attributable to the condition of the plants at the time of planting in 1979. While plants were held for 70 days in buckets, they sprouted both roots and shoots; then, the shoots were browsed by beaver before the plants were transferred to deep shade. In the shade, they again sprouted new leaves before being planted in temperatures of 38° C. The resprouted leaves had developed in deep shade and wilted immediately upon transplanting. A widespread shedding of bark was noted on the slips that did not survive. In contrast, when dormant material was planted at Cold Springs in May 1980, nearly 100 percent of the slips that were 100 cm tall became established.

134. This species should be suitable for use throughout the

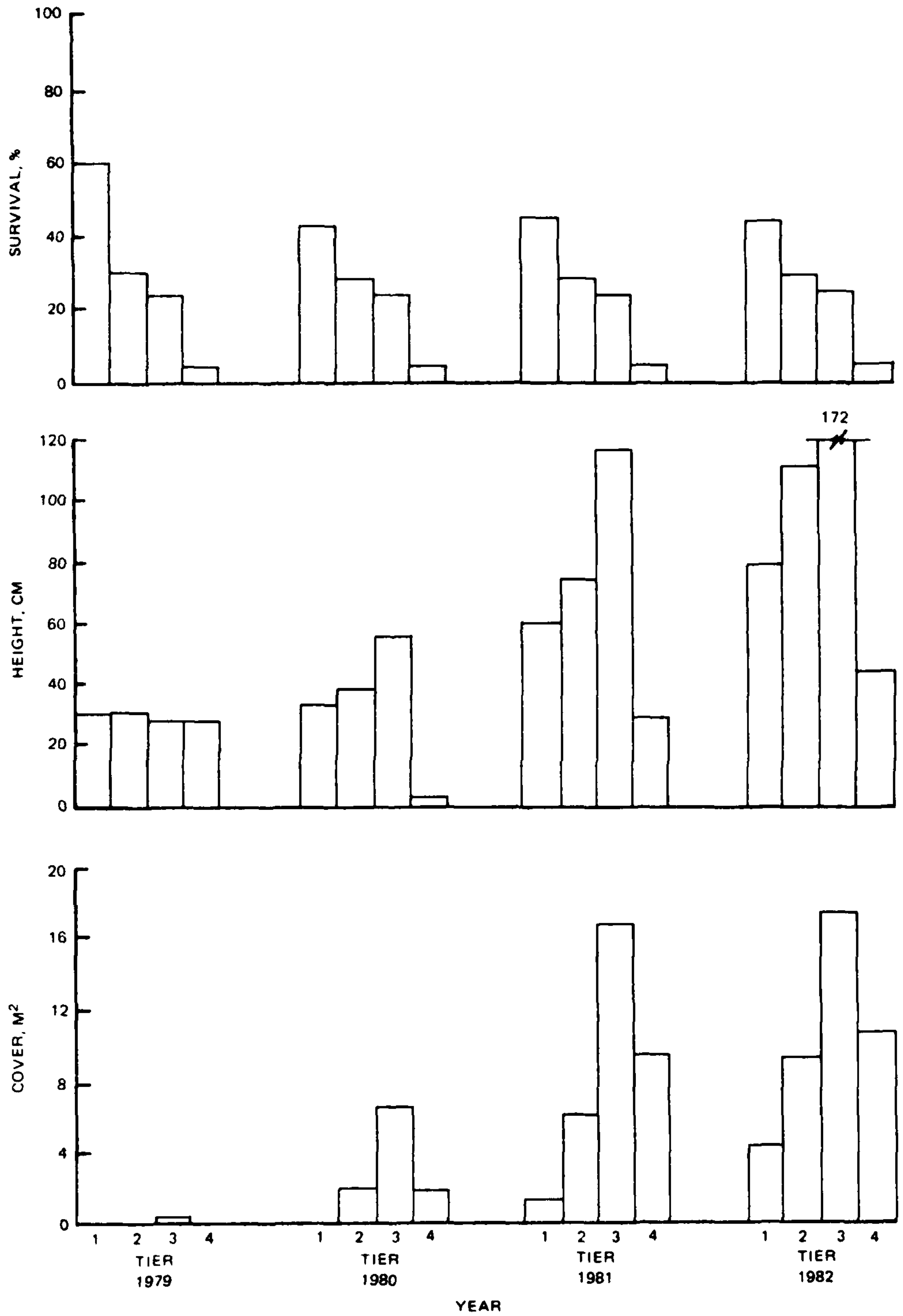

Figure 27. Survival, height, and cover of *Salix purpurea* var. *nana* at four flooding depths at the control pool

drawdown zone and on reservoir margins. The plants should be protected from beaver.

135. <u>*Sambucus cerulea*.</u> The initial survival of *Sambucus* was very poor and ranged from 2 percent on Tier 1 to 21 percent on Tier 3. Mortality was 100 percent by the middle of 1980 on all inundated tiers. Survival declined each year on Tier 4, from 18 percent in 1979 to 5 percent in 1982. Growth of surviving plants was slow during the first 3 years and declined slightly during the fourth year (1982). Maximum height was only 34 cm and maximum area covered was 0.4 m^2.

136. Wildlife did not use this species, and no insect usage or damage was observed. The plants were chronically chlorotic, and portions of the leaves were necrotic yearly.

137. This species is not suitable for use in revegetating shorelines under the conditions of this study. However, several healthy *Sambucus* plants were observed within the McNary Wildlife Park, which suggests there may be some value in its use in moist and upland habitats.

<u>Volunteer plants</u>

138. Plants that invaded check plots at the control pool are listed in Tables 15 and 16. Only those species with densities greater than five plants/square metre on any sampling date and on any tier (contour) are listed.

139. Twenty species were present in the woody check plots, and 23 species were present in the herbaceous check plots. Of these, 14 species were common to both categories of check plots. Generally, the number of species on a given contour doubled or tripled between 1980 and 1981, and then the number of species remained relatively stable. The number of species on the lowest contour (Tier 1) was only about half the number on the upper three contours, which were similar.

140. *Eleocharis coloradoensis* (dwarf spikerush) dominated the lowest contour (Tier 1), and plants were so numerous that data for 1981 and 1982 are expressed as percent cover instead of plants/square metre. Cover of dwarf spikerush increased each year and, by July 1982, there was 78-percent cover on the nonplanted plots on Tier 1. Other species

Table 15

Density of Volunteer Species in Herbaceous Check Plots at the Control Pool in September or October 1980 through 1982*

Species	Plants/Square Metre											
	3- to 4.5-ft Flooding (Tier 1)			1.5- to 3-ft Flooding (Tier 2)			0- to 1.5-ft Flooding (Tier 3)			No Flooding (Tier 4)		
	1980	1981	1982	1980	1981	1982	1980	1981	1982	1980	1981	1982
Ambrosia spp.	0	0	0	0	0	0	0	0	0	0	7	0
Bromus tectorum	0	0	0	0	0	0	0	0	0	47	112	40
Carex vulpinoidea	0	0	21	0	6	22	0	0	7	0	0	0
Centaurea spp.	0	0	0	0	0	0	0	0	0	0	0	9
Conyza canadensis	0	0	0	0	0	3	0	7	0	121	7	16
Cyperus esculentus	0	0	0	0	22	0	0	0	0	0	0	0
Deschampsia caespitosa	0	0	7	0	2	62	0	26	59	32	0	10
Elaeagnus angustifolia	0	0	0	0	0	0	0	0	0	7	67	3
*Eleocharis coloradoensis***	372	42	78	257	1	14	0	0	0	0	0	0
Eleocharis palustris	0	0	0	0	0	10	0	0	0	0	0	0
Epilobium spp.	0	0	0	6	0	32	42	74	37	0	169	91
Gratiola spp.	0	49	229	0	199	46	0	0	0	0	0	0
Juncus spp.	0	0	3	0	2	6	0	0	10	0	0	0
Panicum capillare	0	0	0	0	0	0	0	12	0	0	11	20
Poa annua	0	0	0	6	4	22	0	18	9	0	0	0
Polygonum persicaria	6	10	275	25	120	132	53	26	4	0	0	0
Setaria glauca	0	0	0	0	0	0	0	7	0	0	0	0
Solanum dulcamara	0	0	0	0	0	0	0	0	0	0	0	14
Trifolium wormskjoldii	0	0	0	0	0	0	0	0	0	0	6	6
Trifolium spp.	0	0	0	0	0	0	0	0	0	0	12	0
Verbascum thapsus	0	0	0	0	0	0	0	0	0	6	1	0
Verbena bracteata	0	0	0	0	0	0	6	1	0	0	0	0
Veronica spp.	0	0	3	0	16	0	0	0	0	0	0	0
Total no. of species	2	3	7	4	9	10	3	8	6	5	9	9

* 1982 data taken in July. Only species with more than five plants/square metre on any date are listed.

** Data for 1981 and 1982 are expressed as percent cover.

Table 16

Density of Volunteer Species in Woody Check Plots at the Control Pool in September or October 1980 through 1982*

Species	Plants/Square Metre											
	3- to 4.5-ft Flooding (Tier 1)			1.5- to 3-ft Flooding (Tier 2)			0- to 1.5-ft Flooding (Tier 3)			No Flooding (Tier 4)		
	1980	1981	1982	1980	1981	1982	1980	1981	1982	1980	1981	1982
Bromus tectorum	0	0	0	0	0	0	0	0	0	90	332	166
Carex vulpinoidea	0	3	4	0	6	10	0	1	2	0	0	0
Conyza canadensis	0	0	0	0	2	0	5	10	0	109	124	10
Cyperus spp.	0	0	0	0	37	27	0	0	0	0	0	0
Deschampsia caespitosa	0	0	0	0	10	39	1	28	57	0	1	0
Elaeagnus angustifolia	0	0	0	0	0	0	0	0	0	8	17	14
*Eleocharis coloradoensis***	196	50	78	94	1	0	0	0	0	0	0	0
Eleocharis palustris	0	3	7	0	0	20	0	0	0	0	0	0
Epilobium spp.	0	0	0	0	5	27	8	13	42	0	20	10
Gratiola spp.	0	85	897	7	192	138	0	32	2	0	0	0
Juncus spp.	0	0	2	0	0	24	0	2	4	0	0	0
Lycopsis spp.	0	0	0	0	0	15	0	0	4	0	0	0
Melilotus alba	0	0	0	0	0	1	5	0	3	5	4	5
Morus alba	0	0	0	0	0	0	0	0	1	0	0	0
Panicum capillare	0	0	0	0	0	0	3	17	0	0	15	0
Poa annua	1	1	2	4	3	22	0	9	10	0	0	0
Poa pratensis	0	0	0	0	0	0	0	13	2	0	0	0
Polygonum persicaria	1	15	55	27	103	49	50	8	12	0	0	0
Portulaca spp.	0	0	0	0	0	0	0	0	0	0	0	0
Solidago occidentalis	0	0	0	0	4	0	0	8	0	0	0	0
Total no. of species	3	6	7	5	10	11	6	11	11	4	7	6

* 1982 data taken in July. Only species with more than five plants/square metre on any date are listed.
** Data for 1981 and 1982 are expressed as percent cover.

that were numerous on this contour were *Polygonum persicaria* and *Gratiola* spp.

141. *Eleocharis coloradoensis* dominated the second tier in 1980, but the population decreased dramatically in 1981. Thereafter, *Polygonum persicaria* and *Gratiola* spp. were codominant on this tier and, in 1982, *Deschampsia caespitosa* also became a codominant species. *Epilobium* spp. and *Poa annua* were also numerous in the nonplanted plots in 1982.

142. *Polygonum persicaria* and *Epilobium* spp. dominated the third tier plots in 1980, but thereafter, *P. persicaria* declined and was replaced by *Deschampsia caespitosa* as the codominant species during 1981 and 1982. *Gratiola* spp. was abundant on check plots in the woody block in 1981, but was completely absent from plots in the herbaceous block. This apparent discrepancy cannot be explained, as *Gratiola* was the dominant species in herbaceous check plots on Tier 2 in 1981.

143. On the nonflooded tier, *Bromus tectorum*, *Conyza canadensis*, and an *Epilobium* species were codominant every year. Many *Elaeagnus angustifolia* seedlings (67/square metre) became established on the herbaceous check plots in 1981, but this number diminished to only 3/square metre *E. angustifolia* plants in 1981, and this number remained relatively constant in 1982.

144. Of the five species that were dominant or codominant on the inundated tiers, three were species that were planted in the pool (*Eleocharis coloradoensis*, *Polygonum persicaria*, and *Deschampsia caespitosa*). Reproductive structures or seed of *Gratiola* spp. and *Epilobium* spp. came from other sources. Conversely, none of the dominant or codominant species on the noninundated tier were species that had been planted at the pool. However, it is anticipated that *Elaeagnus angustifolia*, a planted species, would dominate eventually.

Transplant Performance - Cold Springs

145. In addition to treatment effect, several abiotic and biotic factors combined to reduce species survival and plant growth at the Cold

Springs mudflat site. Three contours at 0.25-ft-elevation intervals were established at Cold Springs. When the forebay elevation was at gross pool level, the tiers were submerged a maximum of 2.5 ft (76 cm). Treatments of water, depths, and durations fluctuated in nonrandom, indeterminate fashions. As shown in Table 4, treatments (pool elevations) varied considerably, but tended to be flooded.

146. The three most influential factors other than treatment that affected first-year survival occurred in sequence from early August 1979 through March 1980. In early August, a bloom of the filamentous algae *Cladophora* developed a massive cover on the herbaceous and woody plants. When the forebay elevation was high, the algae floated and shaded the plants. When the forebay elevation was low, the algal mats weighed down and smothered many of the surviving plants. The stiffer herbaceous species, such as softstem bulrush (*Scirpus validus*) and cattail (*Typha latifolia*), and the woody species that had not already succumbed to treatment withstood the weight of the mat. Plants weighed down by the algal mats did not recover. The algal mat persisted until colder weather arrived during October.

147. The wildlife were the second factor to affect the plants at Cold Springs. In particular, waterfowl grazed the remaining herbaceous plots, and muskrats harvested bulrush and cattail. The bulrush recovered, but the cattail did not.

148. During January and February 1980, low temperatures froze the water at this site, so that woody stems developed an ice accumulation at the water surface. The buoyancy of the ice and wave action combined to extract the woody stems. Nearly all woody transplants were removed. The only species that survived were the willows, but these subsequently succumbed to treatment. Several plants survived through two more summers, but plant growth was very limited; plant height did not exceed 20 cm.

149. The only species that survived to the completion of the experiment from the 1979 planting was softstem bulrush (*Scirpus validus*). It remained in eight of the twelve original plots. Of these, plants in

all but one plot grew in an outstanding manner. Table 17 gives height and cover data for these plots.

Table 17

Scirpus validus Height and Cover, July 1982, Cold Springs

Parameter	Tier 1	Tier 2	Tier 3
Height (cm)	151	162	153
	134	172	205
			195
			200
Mean (cm)	143	167	213
Area (m^2)	14.98	12.34	13.22
	0.36	13.53	8.18
			18.41
			23.06
Mean (m^2)	7.67	12.94	15.72

150. These plots were not weeded during the experiment; thus, the data indicate the ability of *S. validus* to expand under the test conditions. Although the species survived on all three tiers, the greatest number of plots containing live plants was on the third tier; there were only two plots with live plants in each of the lower two tiers. Seven of the plots were protected from the full force of the winter wind and wave action by the presence of a small island or by being close to the main shore. Plants in one plot on the first tier that received more exposure grew poorly compared to the more protected plots.

151. After the first year's survival and growth performance was assessed, it was suspected that a primary contributing factor to the overall poor performance at Cold Springs was initial planting height. In the original experiment, all plants had an initial height of 6 in. To test the influence of transplant height, three species were planted with an initial planting height of 90 cm. This planting height permitted some stems and leaves to be continually above gross pool elevation. This also permitted algae to cling to the lower portions of the stem

without adversely affecting leaf and stem formation above the high-water line. Greater plant survival and growth was anticipated from the taller shoots because more photosynthetic tissue would be exposed to light, thereby increasing root growth. The better developed roots should tend to increase anchorage against the winter ice formation.

152. The three species *Salix fragilis*, *Salix purpurea* var. *nana*, and *Cornus stolonifera* were planted in June 1980. The plant growth in 1980 was greater than that occurring prior to the algal bloom in 1979. However, wildlife again impinged upon the plants. One or more beavers harvested willows from the entire experiment, starting first with the *Salix fragilis* and moving on to the *Salix purpurea* when the supply of the former was exhausted. The animal also harvested some dogwood but did not completely harvest the plots. The plants were cut to within a centimetre or two of the soil surface, and they did not recover the following year.

153. Because of the relatively good growth of the willows in 1980 before the beaver cut them, twelve plots were replanted with *Salix fragilis* in 1981 and enclosed with 2-in. woven poultry wire to exclude the beavers. These willows were planted using material of two heights: 36 cm (short) and 86 cm (tall). The shorter planting height greatly reduced establishment (Table 18). The enclosures were successful, and plant growth was comparable to the first year's growth at the control pool. Again, in the winter of 1981-1982, ice accumulated on the stems of the plants and extracted many of them. The plants that survived the ice accumulation (all plants accumulated ice) were those that were most protected from the wave action by the island. The experiment was repeated in the spring of 1982. In July 1982, beaver penetrated the enclosures, apparently by forcing the wire between posts to collapse during a period of high water, and cut the willows off at either the high-water mark or just above the soil surface. Those plants that were cut near the soil surface succumbed as in previous years, but those that were cut at the high-water mark regrew quickly.

154. In 1980, four additional herbaceous species were planted: the sedges *Carex lynbyei* and *Carex sheldonii*; the smartweed, *Polygonum*

Table 18

Effect of Shoot Length of *Salix fragilis* at Time of Planting on Survival and Growth

		Shoot Length at Planting							
		Tall (86 cm)				Short (36 cm)			
Year of Planting	Evaluation Date	Tier	Height cm	Area cm^2	Survival %	Tier	Height cm	Area cm^2	Survival %
1981	Sep 1981	1	103	592	98	1	26	56	16
		2	96	532	96	2	36	79	38
		3	105	723	100	3	59	171	56
	May 1982	1	59	697	28	1	0	0	0
		2	46	288	32	2	15	507	11
		3	92	1,027	71	3	32	127	25
	July 1982	1	50	1,588	28	1	0	0	0
		2	53	1,886	32	2	13	581	11
		3	59	1,352	71	3	22	628	25
1982	July 1982	1	87	395	92	1	48	178	100
		2	120	826	92	2	63	323	98

persicaria; and duck-potato, *Sagittaria latifolia*. Table 19 summarizes the performance of these plants during the season of planting. *Carex sheldonii* succumbed after 2 months. The sedge *Carex lyngbyei* and smartweed did not survive the first winter. However, 55 percent of the duck potato plants survived the winter. In July 1981, duck potato surpassed 50-percent coverage on the third tier and 25- to 50-percent coverage on the first and second tiers. The lower values in October 1980 resulted from senescence of the aereal parts. In early spring, waterfowl or muskrats extirpated the tubers, and no plants survived on the lowest tier. On the second and third tiers, 25 and 50 percent of the plots had live plants. By September, survival had declined to zero on the lowest tier and 25 percent on the second and third tiers. Cover decreased to less than 25 percent in the surviving plots. Plants remained alive in 1982, but they did not grow well.

Table 19

Performance of Four Herbaceous Species, October 1980

	Tier	Plants/Plot	Height (cm)	Cover*
Carex lyngbyei	1	2.3	23.2	1.8
	2	5.0	21.3	2.3
	3	6.5	24.3	2.8
Carex sheldonii	1	0.0	--	1.0
	2	0.0	--	1.0
	3	0.0	--	1.0
Polygonum persicaria	1	2.5	28.1	1.3
	2	0.5	19.7	1.0
	3	2.0	11.8	1.0
Sagittaria latifolia	1	3.3	30.8	1.5
	2	6.8	25.3	1.0
	3	6.3	--	1.0

* Mean values: 1, <1 percent; 2, 1-10 percent; 3, 11-25 percent.

155. The growth and survival of *Sagittaria* in the first months after planting in 1980 and the wildlife usage indicated that this species warranted further research. A replicated experiment was established

in 1981 in which duck potato was planted in exposed and enclosed plots. Enclosed plots were covered with 2-in. woven poultry wire. These plants performed well, as in the previous year. Some of the plots exceeded 90-percent cover. Waterfowl grazed the leaves and petioles of the exposed plants as in 1980. During the fall of 1981, muskrats and waterfowl extirpated plants in and around the exposed plots but did not appear to enter the covered plots. In the spring of 1982, duck potato was observed around the periphery of the extirpated area, but very few plants grew within the covered plots. Survival on a plot basis was 50 percent and, on a per plant basis (one shoot system equaling one plant), the survival was below 10 percent. The low recovery within the covered plots appeared to be due to siltation. Silt in the covered plots was 3 to 6 cm deeper than on the surrounding area.

Transplant Performance - Sand Beach

156. In June 1979, a shoreline experiment was established on a sand beach that consisted of three contours of plots containing the same species planted at the control pool except for *Cornus stolonifera*. Two of the contours were in the drawdown zone, with a maximum inundation of 2 ft on the lowest tier. The uppermost tier was just above gross pool elevation. During the third week after planting was completed, two windstorms struck the site. In all, the resultant wind and wave action removed or covered 86 percent of the plots. Reestablishment of the experiment was economically impossible. At the end of the 4-year study, the site contained eighteen surviving plots or 6 percent of the original 324. Fourteen of these were woody plots and four were herbaceous plots. Five woody plots remained on the second tier and the rest were on the third tier. One of the four herbaceous plots was on the second tier while the other four were on the upper tier.

157. Softstem bulrush (*Scirpus validus*) was the only herbaceous species that was not washed out or buried. Growth of this species was stable, with only small changes in the area covered during the first three seasons. However, in 1982, bulrush began to expand laterally

through rhizome extension. Other herbaceous species that survived on the third (not inundated) tier were tufted hairgrass (*Deschampsia caespitosa*) and the sedges *Carex vulpinoidea* and *C. rostrata*. Rodents grazed heavily on hairgrass, and by July 1982, hairgrass cover was less than 10 cm^2. Two clumps of *Carex vulpinoidea* flowered in 1981 but failed to flower in 1982. Foliage was chlorotic in 1982. Wildlife apparently did not use this species. Cover of *Carex rostrata* increased substantially during the four seasons. It flowered each year after the first season, but was chronically chlorotic.

158. A summary of the woody plant survival is given below. The mean number of plants per plot surviving was calculated on the basis of the plots that remained after the windstorms.

Species	Tier 2	Tier 3
Sambucus cerulea	0.0	0.0
Salix fragilis	2.5	3.0
Elaeagnus angustifolia	4.0	4.5
Morus alba	5.0	8.5
Salix purpurea	0.0	1.0
Rosa multiflora	0.0	2.0
Ribes aureum	2.0	2.0
Salix lasiandra	0.0	0.0
Robinia pseudoacacia	0.0	0.0

159. Mulberry (*Morus alba*) survived in the greatest numbers while crack willow (*Salix fragilis*) achieved the best growth. In March 1982, several crack willow plants were cut to the soil surface by beaver, but they had regrown substantially by July 1982. The growth of crack willow and golden currant (*Ribes aureum*) approached or exceeded the growth of the same species on the fourth tier of the control pool.

160. Although species frequency and density were not determined for pioneer species at Bobbie's Beach, general notes were taken. The first year, the pioneer vegetation consisted primarily of cocklebur (*Xanthium* spp.) and russian thistle (*Salsola kali*) with scattered four-o'clock (*Oenothera* spp.) plants.

161. In 1981, the dominant volunteer species was white sweet-clover (*Melilotus alba*) down to the high-water mark with a scattering of *Xanthium* spp., *Conyza* spp., *Rumex crispus*, *Oenothera* spp., *Salsola kali*, big sagebrush (*Artemesia tridentata*), and cheatgrass (*Bromus tectorum*). In 1982, the single herbaceous check plot contained cheatgrass and sedge (*C. rostrata*), which invaded from the adjacent plot. The second tier woody check plots contained sparse cheatgrass and a mixture of the previously mentioned species with no single species dominant in either frequency or cover. One of the woody check plots on the third tier washed out and the other contained cocklebur, four o'clock, and cheatgrass. The climax community could be riparian in nature with the colonial willow species *Salix exigua* extending into the site, or the climax community could consist of sagebrush, bitterbrush, and cheatgrass. This community is the dominant rangeland community of the surrounding hillsides.

162. The surviving woody plants most resembled plants on the fourth tier of the control pool, although none of the species exceeded the performance of control pool species. Russian olive (*Elaeagnus angustifolia*), for instance, was short and spindly compared with plants of this species at the control pool. Multiflora rose (*Rosa multiflora*), crack-willow (*Salix fragilis*), and *Salix purpurea* var. *nana* flowered. The remaining species did not.

163. After the loss of plots during the first season due to erosion and sand deposition, beach stabilization and planting-technique studies were undertaken. The first study consisted of three similar techniques. On the lowest level, reed rolls constructed from woven poultry wire and three plant species (soft-stem bulrush (*Scirpus validus*) and the sedges *Carex rostrata* and *C. obnupta*) were used. Reed rolls were partially buried in the soil and weighted with rocks. The reed rolls were then wired to 3-ft lengths of rebar driven flush with the soil surface.

164. At an elevation 12 in. higher on the bank, 10- by 10-ft willow mats were evaluated. Plots were excavated to a depth of 8 in. and then 10-ft lengths of the willow *Salix exigua* were placed in the excavation perpendicular to the shore so that the entire plot was

covered. Intermixed with these branches were several 10-ft lengths of white mulberry (*Morus alba*) cut from a nearby bush. The willow was collected from a nearby riparian area. Mats were anchored using two 10-ft lengths of rebar laid parallel to the shore and across the branches. Three-foot lengths of rebar, driven flush with the soil surface, were attached to the longer sections of rebar to anchor the mats. Baling wire also was interwoven through the width of the mat in four places. Finally, the willow mat was covered with sand to the level of the original soil surface.

165. The third planting technique evaluated willow fascines (bundled cuttings) for bank stabilization. This consisted of placing 12-in.-diam fascines constructed from 3-year-old *Salix exigua* branches, in trenches 10 ft long and 1 ft wide. Fascines were anchored with three live willow stakes per side and covered with sand to the original soil depth. Fascines were located 1 ft higher on the sand bank than the willow mats. All treatments (planting methods) were replicated four times.

166. The vegetation in the reed rolls survived 2 to 3 weeks, but did not become established. Willow mats and fascines produced some shoots, but these either did not emerge or subsequent sand deposition buried them. At the end of the growing season, no shoots were present.

167. One of the wattles sprouted and survived to the end of the experiment. *Salix exigua* is a colonial species, but no colonial growth from the wattles was observed in the two seasons after planting. Aside from the burial depth of the fascines and mats, which probably contributed to their failure, the sites underwent considerable sand deposition.

168. The second willow demonstration was established in May 1981, again using *Salix exigua*. A trench 24 in. deep and 50 ft long was dug parallel to and just inside the exclosure fence, which was constructed around the original experiment. Two- to three-year-old rooted branches that were 48 in. long were planted vertically in the trench at 1-ft intervals. The branches were anchored by weaving them into 4-in. hogwire that was attached to fenceposts driven 4 ft into the soil. Also, four 20-ft trenches, 24 in. deep, were dug perpendicular to the shore and

planted with willow branches at 1-ft intervals. The willow cuttings were anchored with hogwire and fenceposts as before. Trenches were filled to the original soil depth; thus, 2 ft of shoots extended above and below the original soil surface. The shoots were also above the mean gross pool level, which virtually assured that the shoots would not become buried. The willows in this experiment survived well. The fence row had 86-percent survival, while the perpendicular rows had a mean survival of 63 percent (range: 45 to 90 percent). None of the shoots became completely covered, although sand deposition occurred.

169. The plants that succumbed in the rows were generally the farthest away from the water. Soil moisture was present and apparently adequate throughout the duration of the project at those elevations. The cause of plant death is undetermined, as is the cause of death of the five plants along the fence row. Vandals took 6 percent of the plants. The tabulation below gives a summary of the growth performance of plants in this experiment 1 year after establishment.

Treatment	Height (cm)*	Cover (cm^2/plant)
Fencerow	107	4,613
Row 1	64	2,192
Row 2	93	3,740
Row 3	77	2,922
Row 4	73	2,452

* Values are the mean of 10 plants.

170. Little significance should be given to the difference in height between plants in the fence row and those in the perpendicular rows (rows 1 to 4) since some erosion occurred along the fence row and deposition occurred among rows 1 through 4.

171. These data are comparable to first-year or early second-year growth data for other willow species grown at the control pool. These plants produced colonial shoots between the rows. These appeared in the spring of the second year and were confined to the area above the high-water mark. The fence-row plants did not appear to produce any colonial shoots. The tallest of the colonial shoots reached a height of 70 cm and had an approximate area of 800 cm^2 by July 1982.

PART IV: DISCUSSION

172. Although the experimental sites are located in a semiarid region with rainfall of 10-12 in./year, an ample supply of water is available due to the proximity of Lake Wallula. However, extended drawdown periods coupled with low rainfall, especially during spring and fall, could reduce survival of transplants and reduce growth. Four-year results of this study do not indicate this to be the situation.

173. Other environmental constraints such as wave action, algal blooms, ice extraction, and wildlife activity tended to impact the transplants more than drought effects. Shoreline protection from these influences will be a critical aspect in establishing vegetation.

174. Results of this study show that transplanted woody species will tolerate the experimental shoreline sites better than the transplanted herbaceous species. Above the maximum pool levels, volunteer native herbaceous species will invade denuded shoreline areas, especially sandy sites, if both foot and vehicle traffic are prevented.

175. Woody transplants in the drawdown zones should be of sufficient height to withstand surface erosion, wave and upland runoff, deposition, and floodwater depths. Vegetated aerial portions should be above maximum water depths in order to ensure maintenance of physiological processes within the plant. Furthermore, woody species should be planted upright (vertical) in preference to horizontal (wattling). Again, this is to ensure that vegetated portions of the plant are above maximum flood depths and sand deposition.

176. Table 20 lists those herbaceous species suitable for shoreline transplanting. Only 4 of the 19 tested herbaceous species were found to be unsuitable. Generally, most herbaceous species exhibited reduced survival, height, and cover with increasing flood-pool depth and flood duration at the impoundment site. Only *C. aperta*, *C. rostrata*, *C. obnupta*, and *E. coloradoensis* maintained sufficient height, survival, and cover in the deepest water zone (3 to 4.5 ft). Table 20 can be used as a reference for selecting herbaceous species suitable for various inundation depths.

Table 20

Suitability of Tested Herbaceous Plants for Zones Located Just Above to 4.5 ft Below the High-Water Line of Reservoirs with Daily Fluctuation, Central Oregon and Washington

Herbaceous Species	Suitable for Water Depth of: 3 to 4.5 ft	1.5 to 3 ft	0 to 1.5 ft	Upland	Not Suitable
Carex aperta	X	X			
Carex lyngbyei					X
Carex nebraskensis		X			
Carex rostrata	X	X	X		
Carex obnupta	X	X	X		
Carex sheldonii					X
Carex vulpinoidea		X	X		
Deschampsia caespitosa		X	X	X	
Eleocharis coloradoensis	X	X	X		
Eleocharis ovata					X
Eleocharis palustris		X	X		
Juncus balticus			X	X	
Juncus effusus			X		X
Polygonum persicaria			X		
Sagittaria latifolia		X	X		
Scirpus americanus			X	X	
Scirpus validus		X	X		
Trifolium wormskjoldii				X	
Typha latifolia			X		

177. Table 21 lists woody test species and their suitability to several inundation zones. Only two *Salix* species are suitable for all flood depths. As discussed above, transplants should be of sufficient size to have vegetated portions above the water surface at all times. For example, *S. fragilis* transplants should be approximately 6-7 ft long if planted in 3- to 4.5-ft flood zones.

Table 21

Suitability of Tested Woody Plants for Zones Located Just Above to 4.5 ft Below the High-Water Line of Reservoirs with Daily Fluctuations, Central Oregon and Washington

Woody Species	Suitable for Water Depth of: 3 to 4.5 ft	1.5 to 3 ft	0 to 1.5 ft	Upland	Not Suitable
Cornus stolonifera			X	X	
Elaeagnus angustifolia				X	
Morus alba			X	X	
Ribes aureum					X
Robinia pseudoacacia				X	
Rosa multiflora			X	X	
Salix fragilis	X	X	X	X	
Salix lasiandra		X	X	X	
Salix purpurea	X	X	X	X	
Sambucus cerulea					X

PART V: SUMMARY

178. Beginning in June 1979 and ending in July 1982, experiments were conducted to determine the suitability of 29 native and naturalized riparian species for use in reservoir shoreline revegetation projects on the Columbia and Snake Rivers in Oregon and Washington. One experiment was established in a subimpoundment in which water fluctuations were controlled by the investigators, and two experiments were conducted on natural shoreline sites: one on a mudflat site and the other on a sand beach site. Water fluctuations on the shoreline sites varied according to the dictates of power, navigational, and fisheries needs.

179. The impact of weather and wildlife confounded treatment (flooding) effects on plant growth and survival on the shoreline sites. The only species that survived on shoreline sites for four growing seasons was softstem bulrush (*Scirpus validus*). Plant performance was much better in the control impoundment, where the effects of wave energy, prolonged periods of inundation, weather, and wildlife were minimized. In the control impoundment, where the water fluctuated regularly, the most successful species were willows (*Salix fragilis* and *S. purpurea* var. *nana*), dwarf spikerush (*Eleocharis coloradoensis*), and two sedges (*Carex obnupta* and *C. rostrata*). Inundation depth and duration, which were directly proportional in this study, had a marked effect on the performance of other species.

180. These experiments identified several species that are suitable for shoreline revegetation of the drawdown zones of Lake Wallula. Forces other than inundation that limit plant establishment in reservoirs also were identified, but further research in these areas is needed. The information gathered in this study, while directly applicable to revegetation at Lake Wallula, may be extended in general to other power production reservoirs along the central Columbia River Basin and the Snake River.

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APPENDIX A: SCIENTIFIC AND COMMON PLANT NAMES USED IN TEXT

Scientific Name	Common Name
Ambrosia spp.	ragweed
Artemesia tridentata	big sagebrush
Atriplex spinosa	spiny hopsage
Bromus tectorum	cheatgrass
Carex aperta	Columbia sedge
Carex lyngbyei	Lyngbye's sedge
Carex nebraskensis	sedge
Carex obnupta	slough sedge
Carex rostrata	beaked sedge
Carex sheldonii	sedge
Carex vulpinoidea	sedge
Centaurea spp.	star thistle
Chrysothamnus spp.	bitterbrush
Conyza canadensis	horseweed
Cornus stolonifera	red-osier dogwood
Cyperus esculentus	nut grass
Deschampsia caespitosa	tufted hairgrass
Elaeagnus angustifolia	Russian olive
Eleocharis coloradoensis	dwarf spikerush
Eleocharis ovata	spikerush
Eleocharis palustris	creeping spikerush
Eleocharis parvula	spikerush
Epilobium spp.	willowweed
Festuca spp.	fescue
Gratiola spp.	hedge hyssop
Juncus balticus	baltic rush
Juncus effusus	soft rush
Lycopsis spp.	bugloss
Melilotus alba	white sweetclover
Morus alba	white mulberry

(Continued)

Scientific Name	Common Name
Oenothera spp.	four o'clock
Panicum capillare	panic grass
Phalaris spp.	canary grass
Poa annua	blue grass
Poa pratensis	Kentucky bluegrass
Polygonum persicaria	smartweed
Populus deltoides	eastern cottonwood
Populus trichocarpa	black cottonwood
Portulaca spp.	portulaca
Purshia tridentata	bitterbrush
Ribes aureum	golden currant
Robinia pseudoacacia	black locust
Rosa multiflora	multiflora rose
Rumex crispus	curly dock
Sagittaria latifolia	duck potato
Salix exigua	slender willow
Salix fragilis	crack willow
Salix lasiandra	yellow willow
Salix purpurea var. *nana*	purple osier willow
Salsola kali	Russian thistle
Sambucus cerulea	blue elderberry
Scirpus americanus	sword grass
Scirpus validus	softstem bulrush
Setaria glauca	foxtail grass
Solanum dulcamara	nightshade
Solidago occidentalis	goldenrod
Trifolium wormskjoldii	clover
Typha latifolia	cattail
Verbascum thapsus	wooly mullein
Verbena bracteata	verbena
Veronica spp.	speedwell
Xanthium spp.	cocklebur

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